DOCUMENT RESUME

ED 240 324 CE 038 198

AUTHOR	Teague, Cash; Pewewardy, Garner
TITLE	Industrial Electricity: Motors. Oklahoma Trade and Industrial Education.
INSTITUTION	Oklahoma State Board of Vocational and Technical Education, Stillwater. Curriculum and Instructional Materials Center.
SPONS AGENCY	Oklahoma State Dept. of Vocational and Technical Education, Stillwater. Div. of Trade and Industrial Education.
PUB DATE	84
NOTE	502p.
AVAILABLE FROM	Curriculum and Instructional Materials Center, Oklahoma State Board of Vocational and Technical Education, 1515 West Sixth Street, Stillwater, OK 74074 (Teacher--$18.50, Student--$18.00).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF02 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Adult Vocational Education; Behavioral Objectives; Competency Based Education; Curriculum Guides; *Electricity; *Electric Motors; *Equipment Maintenance; *Industry; Learning Activities; Postsecondary Education; Safety; Secondary Education; Tests; *Trade and Industrial Education; Transparencies; Units of Study
IDENTIFIERS	*Industrial Electricity

ABSTRACT

This curriculum guide provides competency-based instructional materials for training in the field of industrial electricity. Materials are not geared to a specific grade level and may be used with secondary and postsecondary students as well as part- and full-time adult students. The guide includes three sections and ten instructional units. Each unit of instruction consists of eight basic components: performance objectives, teacher activities, information sheets (content essential for meeting the cognitive objectives), assignment sheets (applications of knowledges that are prerequisites to skill development), job sheets (procedures to complete a manipulative or psychomotor skill), transparency masters, tests, and test and assignment sheet answers. Section A on DC motor systems contains two units: DC Motors and DC Motor Controls. In section B on AC motor systems are seven units: Introduction to AC Motors, Shaded Pole Motors, Split Phase Motors, Capacitor Motors, Three Phase Motors, Contactors and Motor Starters, and AC Motor Controls. Section C on motor generators consists of one unit, Motor Generators. (YLB)

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ED240324

Industrial Electricity
Motors

OKLAHOMA TRADE AND INDUSTRIAL EDUCATION

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INDUSTRIAL ELECTRICITY: MOTORS

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FOREWORD

As vocational educators, we have a basic belief that quality vocational programs require the availability and use of quality competency-based instructional materials. This need prompted our department to develop two volumes of instructional materials to provide high-quality training in the field of industrial electricity. This first volume, *Industrial Electricity: Motors*, contains information on DC and AC motors and motor generators.

We feel confident that the information contained in this publication is critical for technicians working with new and emerging technologies. The instructional materials should be adapted, personalized, and localized so that this publication will become a vital part of the teaching/learning process.

We hope that these materials will help you prepare competent individuals for the work force.

Francis Tuttle, Director
Oklahoma State Department of
Vocational and Technical Education

Ivan Armstrong, State Supervisor
Trade and Industrial Education

PREFACE

Today's work force must be competent and capable of working with new and emerging technology. Our industries today require individuals to possess competencies in the field of industrial electricity. If properly implemented, the materials contained in this publication will help prepare individuals for the work force.

The materials are competency based and are not geared to a specific grade level. Secondary and postsecondary students, as well as part-time and full-time adult students, will benefit from studying these materials. The strength of the materials rests in the assignment and job sheets. These sheets provide specific applications to meet the needs of business and industry. A standard of 85 percent has been established for each unit of instruction. A student must achieve this standard or be responsible for studying the material and retaking the test.

Bob Patton, Coordinator
Curriculum and Instructional
Materials Center

ACKNOWLEDGEMENTS

Planning and Reviewing Committee

The authors of this publication are grateful for the generous contribution of time, expertise, and cooperation given by committee members and the schools or industries they represent.

This publication would not have been possible without help from the following people:

Dennis English — Instructor, Central Oklahoma AVTS, Drumright, Oklahoma
Keith Harp — State Department of Vocational and Technical Education, Stillwater, Oklahoma
Bill Hill — State Department of Vocational and Technical Education, Stillwater, Oklahoma
John Humler — Instructor, Tri-County AVTS, Bartlesville, Oklahoma
Herbert Leak, Jr. — Instructor, Northeast Oklahoma AVTS, Pryor, Oklahoma
Mike Moore — Indian Capital AVTS, Muskogee, Oklahoma
Elvis Pennington — Contractor, Stillwater, Oklahoma
James Sharpton — State Department of Vocational and Technical Education, Stillwater, Oklahoma

We would also like to express our appreciation to the following companies for granting permissions for many of the illustrations used in this publication.

Allen-Bradley Company
Milwaukee, Wisconsin

Eaton Corporation,
Cutler-Hammer Products
Milwaukee, Wisconsin

General Electric Company
Louisville, Kentucky

Sooner Rubber Products
Oklahoma City, Oklahoma

Square D Company
Milwaukee, Wisconsin

Westinghouse Electric Corporation
Buffalo, New York

Joyce Sawatzky deserves special recognition for the numerous hours she spent reviewing and revising the manuscript. Thanks to Robert Hilley for his help in reviewing the materials. A great deal of the credit for the readability and clarity of this material goes to the CIMC editing staff under Terra McCluskey. Their help and guidance, their attention to detail, and their concern for a quality product were invaluable in completing this project. Our gratitude goes to Terri Barnes, Sue Buck, Sue Feasley, Susan Walker, and Jerry Weir.

Special recognition goes to staff members from the Curriculum and Instructional Materials Center and the Graphics Division of the State Department of Vocational and Technical Education for the services they offered during the development and publication of this manual. Most notably, recognition goes to Nancy Hilley and Dana Welborne, who provided many of the excellent illustrations used to supplement the instructional materials, and the members of the Communications Center, who, under the supervision of Jenny Fowler, typed and typeset the many drafts and revisions required during development. Those most involved in the typing for this volume include Dona Landreth, Rose Primeaux, Gari Sha Robinson, and Allison McLaughlin. Finally, the services of the Print Shop, under Noel Wilcoxson, produced the quality appearance of this material.

USE OF THIS PUBLICATION

Instructional Units

Industrial Electricity: Motors includes three sections and ten instructional units. A standard format was established in 1970 for development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components that form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, assignment sheets, and job sheets included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following

A. Amount of material that can be covered in each class period
B. Skills that must be demonstrated
    1. Supplies and equipment needed
    2. Amount of practice needed
    3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people who must be contacted

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction, and specific objectives, stating the performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching/learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms that may have been used in this material.

A. Name — The individual supplies a name for objects, events, or people

    Behavioral synonyms: Label, list, letter, record, reiterate, repeat, write

B. Identify — The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

    Behavioral synonyms: Select, mark, match, choose, judge

C. State a rule — The individual communicates a relationship or principle that could be used to solve problems or perform a task

D. Apply a rule — The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: Solve, calculate

E. Describe — The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: Define, discuss, interpret, recite, tell how, tell what happens when

F. Distinguish — The individual selects an object or event from two or more that are easily confused

Behavioral synonyms: Discriminate, differentiate

G. Order — The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: Arrange, sequence, list in order, classify, divide, isolate, sort

H. Construct — The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile

I. Demonstrate — The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis)assemble, (dis)connect

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may also be used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Teachers should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the teacher should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities (pink pages)

This component is included only in teacher material. The suggested activities page assists teachers during the preparation stage of the teaching/learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units to allow time to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in teacher material and green in student material)

Transparency masters provide information in a special way. Transparencies direct the class's attention to the topic of discussion. Transparencies may present new information, or they may reinforce information presented in the information sheet. They are particularly effective when identification is necessary. Make transparencies and place them in the notebook where they will be immediately available for use.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience with the information. They assist students in the application of knowledges that are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided when appropriate and can be used by the student and/or teacher for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomoter skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

Instruments in job sheets are not in order of use. This should be taught in the classroom. In this way, students will not depend entirely on job sheets for instrument setup.

A teacher should demonstrate to students the procedures outlined in each job sheet. Furthermore, the teacher needs to localize the job sheet according to the equipment and supplies available in the local lab or shop situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test, 85 percent in most units, may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each individual question. The final unit grade should be obtained by using the paper/pencil score along with evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the teacher in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *Industrial Electricity: Motors* has been abbreviated IE. The units are then numbered consecutively within each section. An example of a page number is IE-1-A. Since CIMC publications are loose leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder for the units. This is convenient for taking the materials home to study. Upon completion, each unit is then placed in a larger binder. The large binders may be purchased at cost from the CIMC. Some teachers store the materials by units in filing cabinets or boxes until needed. All the units may be given out at once if desired.

For best results, provide student materials for each student. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. All tests are collated at the back of student material and should be removed and stored until needed. Students should be allowed to take their materials home at the end of the year.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning.

Competency Profiles

Competency profiles are folders used to document student performance. The profile contains a list of the specific job competencies that should be achieved prior to leaving the training program.

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DC MOTORS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to troubleshoot and repair a direct current motor. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with direct current motors.
2. Identify components of a direct current motor.
3. Identify the parts of an armature.
4. Match direct current motor parts to their correct functions.
5. Label direct current motor nameplate.
6. Select from a list factors that affect torque.
7. State the purpose of commutation.
8. Name causes of poor commutation.
9. Calculate percentage of speed regulation.
10. Select from a list steps in connecting a shunt motor.
11. Identify types of shunt motor connections.
12. Select from a list procedures to avoid when operating a series motor.
13. Identify types of series motor connections.
14. Identify types of compound motor connections.
15. Label schematic diagrams of shunt, series, and compound motors.
16. Demonstrate the ability to
    a. Use a stroboscope and tachometer to measure motor speed.
    b. Use reverse rotation to locate a direct current motor's neutral plane.

OBJECTIVE SHEET

c. Disassemble, clean, and reassemble a motor.

d. Use a growler to test for shorts in a direct current motor armature.

e. Use a test light to locate opens and grounds in a direct current motor armature.

f. Use a Megger to check field coils for grounds.

g. Use a multimeter to locate opens, shorts, and grounds in a direct current motor.

DC MOTORS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order film *Rotating Machinery Explained: Direct Current Motors*. Available from Bergwall Productions, Inc., 839 Stewart Avenue, Garden City, New York 11530.

B. Obtain one or more copies of *Electrical Maintenance Hints*. Trafford, Pennsylvania: Westinghouse Electric Corporation, Printing Division, 1974. Available through WESCO (Westinghouse Electric Supply Co.), Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania 15222.

C. Make transparency.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives, stating the relevance and use of each in working with direct current motors.

F. Provide students with information, assignment, and job sheets.

G. Discuss information, assignment, and job sheets.

1. Use a disassembled motor to point out individual parts and reinforce new terms shown in Information Sheet, Section I.

2. Discuss components of a DC motor, using Information Sheet, Sections II through V and Transparency #1. Show how individual motor parts may be helpful in the identification of parts and their functions.

3. Discuss factors that affect torque and commutation, using Information Sheet, Sections VI through VIII. Refer to Information Sheet, Section I for review of torque and commutation. Show commutator from real motor.

4. Discuss the need for speed regulation and the process used to determine it. Use Information Sheet, Section IX for text. Assignment Sheet #1 gives the students practice in calculating percentage of speed regulation. Job Sheet #1 allows the student to measure actual motor speeds in the shop.

5. Discuss and demonstrate shunt motor connections, using Information Sheet, Sections X and XI and Assignment Sheet #2, A-D. Be sure to stress the importance of proper connections to prevent motor damage.

SUGGESTED ACTIVITIES

6. Discuss and demonstrate series motor connections, using information Sheet, Sections XII and XIII. Assignment Sheet #2, E-H allows the student to apply the principles of series connections by diagraming motor connections.

7. Discuss and demonstrate compound motor connections, using Information Sheet, Section XIV and Assignment Sheet #2, I-L. Proper comparison of all DC motor types at this point will begin to show their similarities and differences.

8. Discuss and demonstrate neutral plane, and proper disassembly, cleaning, and reassembly of a motor, using Job Sheets #2 and #3. Explain the uses and applications of test equipment. Job Sheets #4 through #7 allow students hands-on experience with the test equipment and DC motors.

H. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency master: TM #1 — Typical DC Motor Nameplate

E. Assignment sheets

1. Assignment Sheet #1 — Calculate Percentage of Speed Regulation

2. Assignment Sheet #2 — Label Schematic Diagrams of Shunt, Series, and Compound Motors

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Use a Stroboscope and Tachometer to Measure Motor Speed

2. Job Sheet #2 — Use Reverse Rotation to Locate a Direct Current Motor's Neutral Plane

3. Job Sheet #3 — Disassemble, Clean, and Reassemble a Motor

4. Job Sheet #4 — Use a Growler to Test for Shorts in a Direct Current Motor Armature

SUGGESTED ACTIVITIES

5. Job Sheet #5 — Use a Test Light to Locate Opens and Grounds in a Direct Current Motor Armature

6. Job Sheet #6 — Use a Megger to Check Field Coils for Grounds

7. Job Sheet #7 — Use a Multimeter to Locate Opens, Shorts, and Grounds in a Direct Current Motor

H. Test

I. Answers to test

III. Unit references

A. Adams, James E. *Electrical Principles and Practices*. New York: McGraw-Hill Book Co., 1973.

B. Cox, Cecil and Bob Patton. *Vocational Agriculture II*. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1978.

C. *Electrical Maintenance Hints*. Trafford, Pennsylvania: Westinghouse Electric Corporation, Printing Division, 1974.

D. Miller, Rex. *Basic Electricity*. Chicago, Illinois: Bennett Publishing, 1978.

E. Rosenberg, Robert. *Electric Motor Repair*. New York: Holt, Rinehart, and Winston, Inc., 1970.

DC MOTORS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Armature — Rotating part of a DC motor that receives electrical energy

B. Armature reaction — Effect that magnetic field produced by current flow in the armature has on magnetic lines of force produced by field coils

C. Commutation — Removal of electrical current from a coil in preparation for reversing current

(NOTE: Magnetism is a byproduct of current.)

D. Commutator — Generally, the part of an armature used to reverse the direction of current

E. Direct current (DC) motor — Rotating machine that converts electrical energy into mechanical energy

F. Eddy current — Current that travels at right angles to the direction of magnetic flux in a metal part; produces unwanted heat

G. Electromotive force (emf) — Electrical pressure or voltage that forces electrical current through a circuit

H. Flux — Total of magnetic lines of force existing in any area

I. Hysteresis — Lagging of changes in the magnetization of a substance behind changes in the magnetic field as the magnetic field is varied

J. Motor brushes — Prepared pieces of carbon used to make electrical contact with rotor, commutator, or slip rings to conduct current to rotor coils

K. Neutral plane — Position of brushes that allows speed to remain constant when rotation is reversed

L. Revolutions per minute (rpm) — Number of revolutions a motor will make in sixty seconds

M. Series motor — Motor in which field coils connect in series with armature

N. Shunt motor — Motor in which field coils connect in parallel with armature

O. Speed control — Change in motor speed caused by placing external resistance in motor field or armature circuit

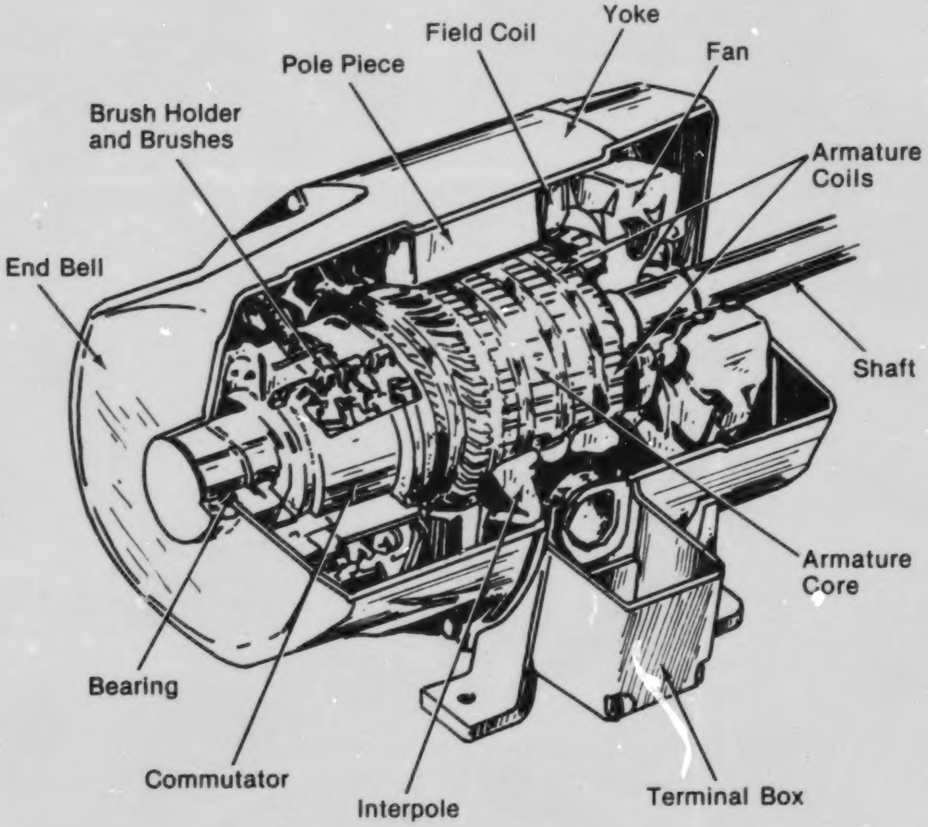
INFORMATION SHEET

P. Speed regulation — Motor's ability to maintain speed when load is applied

Q. Torque — Turning, twisting motion produced by interaction of the two magnetic fields

II. Components of a direct current motor (Figure 1)

FIGURE 1


Yoke
Field Coil
Fan
Pole Piece
Brush Holder and Brushes
Armature Coils
End Bell
Shaft
Armature Core
Bearing
Commutator
Interpole
Terminal Box

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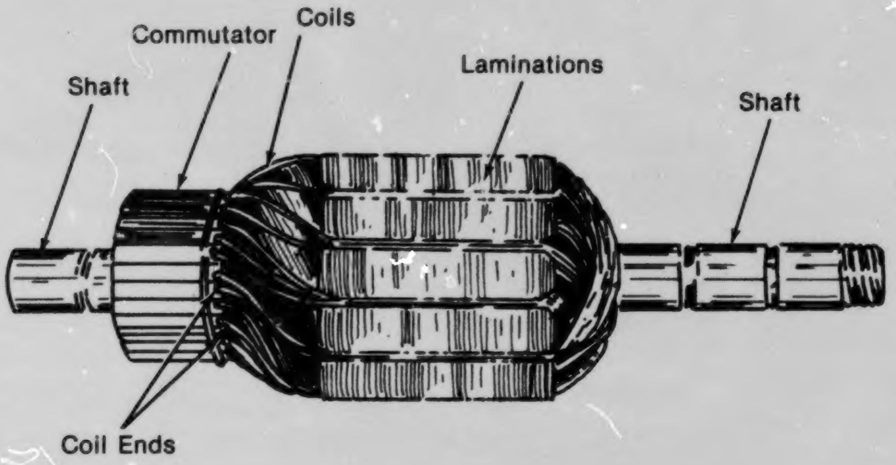
INFORMATION SHEET

III. Parts of an armature (Figure 2)

FIGURE 2



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IV. Functions of direct current motor parts

A. Yoke

1. Provides mechanical support for pole pieces, core, and end bells
2. Serves as a portion of the magnetic circuit

B. Pole pieces (field poles)

(NOTE: Pole pieces are made of laminated silicon steel; they reduce eddy currents and hysteresis.)

1. Support field windings
2. Concentrate magnetic flux

C. Field coils

(NOTE: Field coils are connected series, shunt, or compound.)

1. Connect to form alternate north and south magnetic poles
2. Form electromagnets that produce main field flux

INFORMATION SHEET

D. Armature coils — Receive electrical energy

(NOTE: There are two types of armatures: *simplex* and *wave*.)

E. Commutator

1. Causes current in armature coils to reverse, causing unlike magnetic poles to face each other
2. Provides surfaces on which brushes ride

F. Brushes — Carry external current to commutator and coils

G. Brush holder — Guides brushes on commutator, allows for freedom of movement, and maintains proper spring tension

H. Bearings

(NOTE: There are two general types of bearings: *rolling* and *sliding*.)

1. Support rotating armature
2. Reduce friction for rotating armature

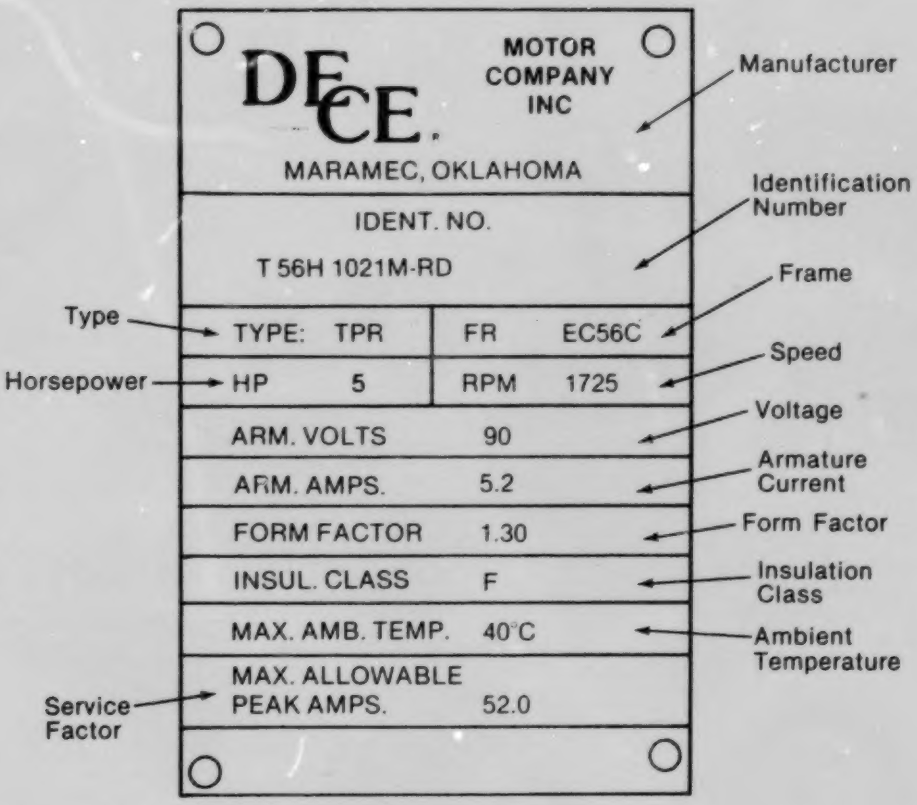
I. End bells

1. House bearings
2. Support brush rigging
3. Align armature shaft

INFORMATION SHEET

V. Direct current motor nameplate data (Figure 3; Transparency #1)

FIGURE 3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TYPE: TPR
FR EC56C
HP 5
RPM 1725
ARM. VOLTS 90
ARM. AMPS. 5.2
FORM FACTOR 1.30
INSUL. CLASS F
MAX. AMB. TEMP. 40°C
MAX. ALLOWABLE PEAK AMPS. 52.0
Manufacturer
Identification Number
Frame
Type
Horsepower
Speed
Voltage
Armature Current
Form Factor
Insulation Class
Ambient Temperature
Service Factor

VI. Factors that affect torque

A. Reversed polarity of field windings

B. Reversed armature leads

C. Bad bearings

D. Improper connection of interpoles

E. Reversed series winding leads

VII. Purpose of commutation — To maintain unidirectional torque by periodically reversing current in armature conductors as the armature conductors move under alternate poles

INFORMATION SHEET

VIII. Causes of poor commutation

- A. Improper brush pressure
- B. Improper position of brushes
- C. Dirty or rough commutator
- D. Improper brushes
- E. Loose brush rigging and pigtail
- F. High or loose commutator bars
- G. Partially shorted armature
- H. Overloaded motor

IX. Calculate percent of speed regulation (Assignment Sheet #1)

$$\text{Percent of Speed Regulation} = \frac{\text{No-Load Speed} - \text{Full-Load Speed}}{\text{No-load speed}} \times 100$$

EXAMPLE: NLS = 1,600 rpm
FLS = 1,500 rpm

$$\text{Percent of Speed Regulation} = \frac{\text{NLS} - \text{FLS}}{\text{NLS}} \times 100$$

$$= \frac{1600 - 1500}{1600} \times 100$$

$$= 6.25$$

X. Steps in connecting a shunt motor

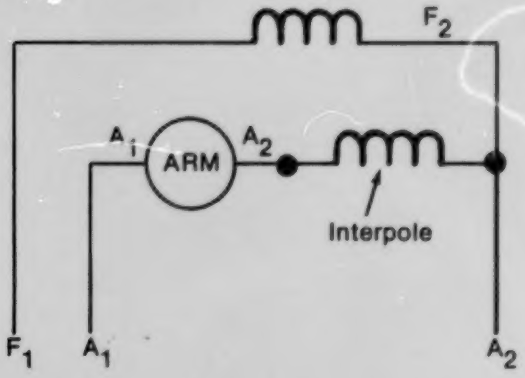
- A. Identify terminal markings
- B. Find directional rotation of motor
- C. Interpret proper types of connections to be made

INFORMATION SHEET

XI. Types of shunt motor connections (Figures 4-7; Assignment Sheet #2)

A. Nonreversible with interpoles

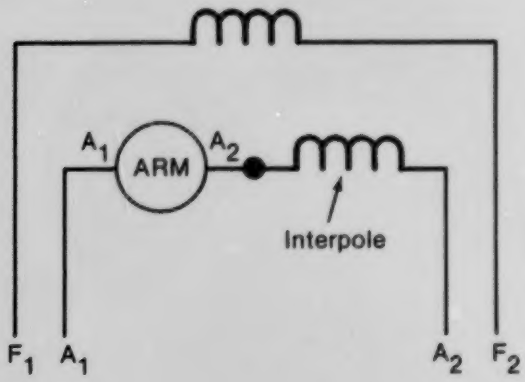
FIGURE 4



F2
A1
ARM
A2
Interpole
F1
A1
A2

B. External reversible with interpoles

FIGURE 5

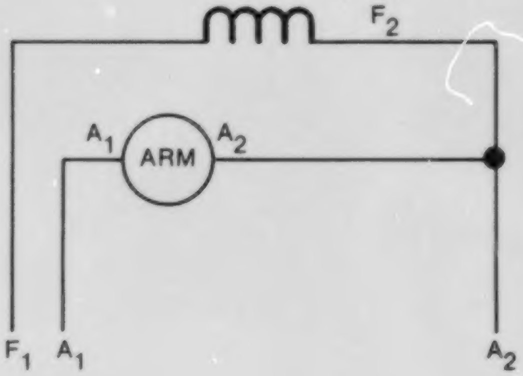


A1
ARM
A2
Interpole
F1
A1
A2
F2

INFORMATION SHEET

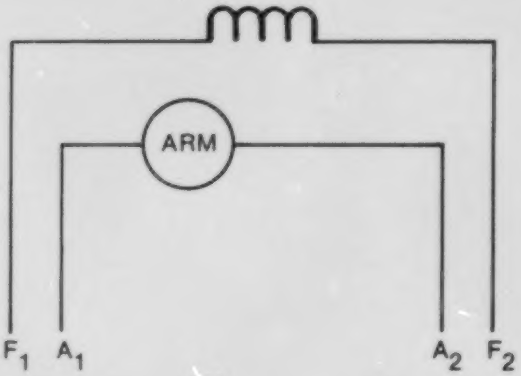
C. Nonreversible without interpoles

FIGURE 6


F2
A1
ARM
A2
F1
A1
A2

D. External reversible without interpoles

FIGURE 7


ARM
F1
A1
A2
F2

XII. Procedures to avoid when operating a series motor

A. Never start without a load

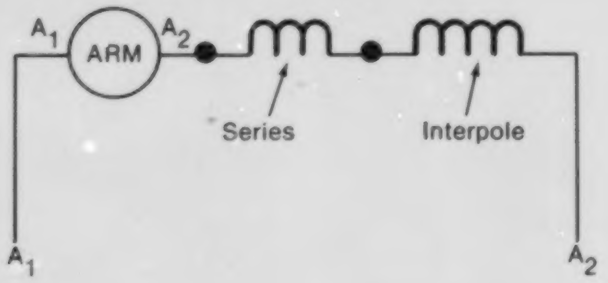
B. Never use a belt pulley

INFORMATION SHEET

XIII. Types of series motor connections (Figures 8-11; Assignment Sheet #2)

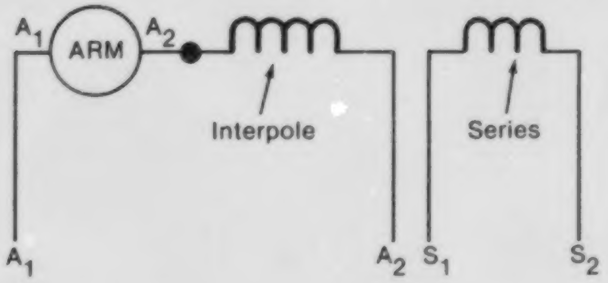
A. Nonreversible with interpoles

FIGURE 8


A_1
ARM
A_2
Series
Interpole
A_1
A_2

B. External reversible with interpoles

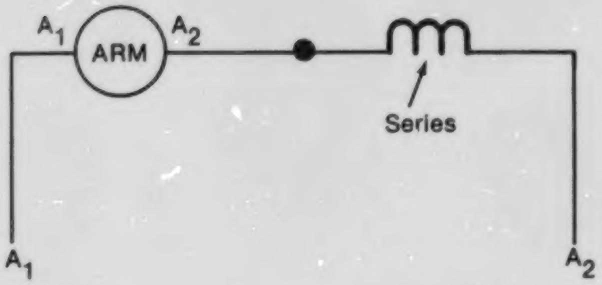
FIGURE 9


A_1
ARM
A_2
Interpole
Series
A_1
A_2
S_1
S_2

INFORMATION SHEET

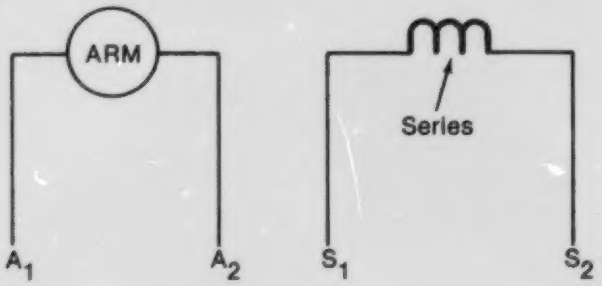
C. Nonreversible without interpoles

FIGURE 10


A1
ARM
A2
Series
A1
A2

D. External reversible without interpoles

FIGURE 11

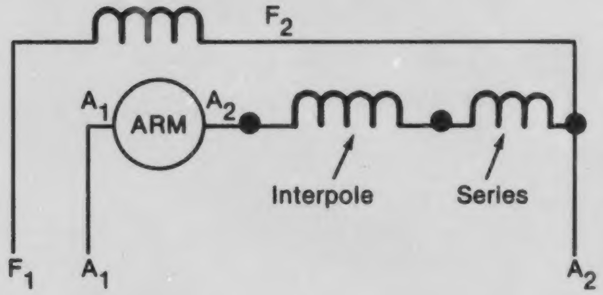

ARM
Series
A1
A2
S1
S2

INFORMATION SHEET

XIV. Types of compound motor connections (Figures 12-15; Assignment Sheet #2)

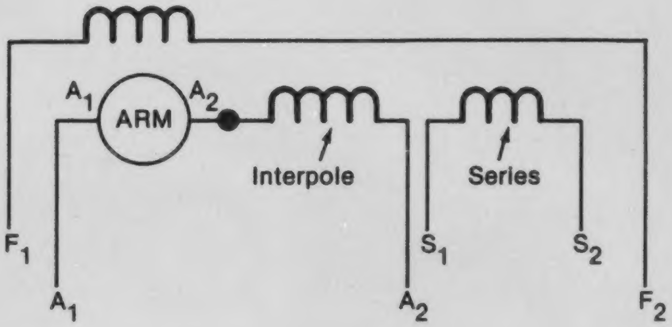
A. Nonreversible with interpoles

FIGURE 12


F2
A1
ARM
A2
Interpole
Series
F1
A1
A2

B. External reversible with interpoles

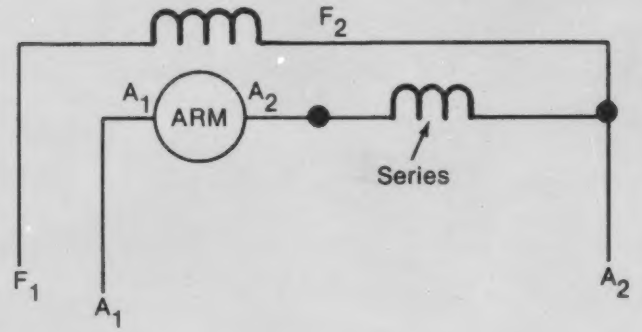
FIGURE 13


A1
ARM
A2
Interpole
Series
F1
A1
S1
S2
A2
F2

INFORMATION SHEET

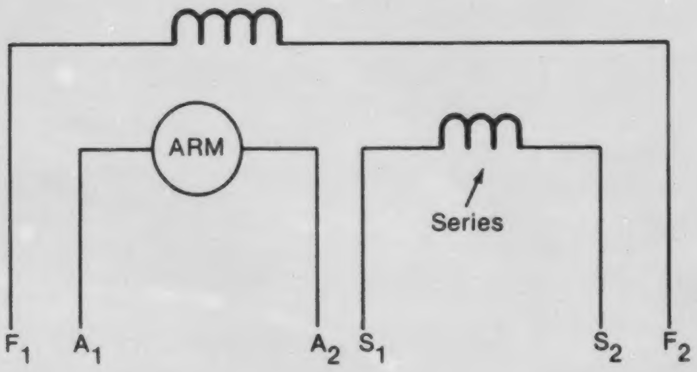
C. Nonreversible without interpoles

FIGURE 14

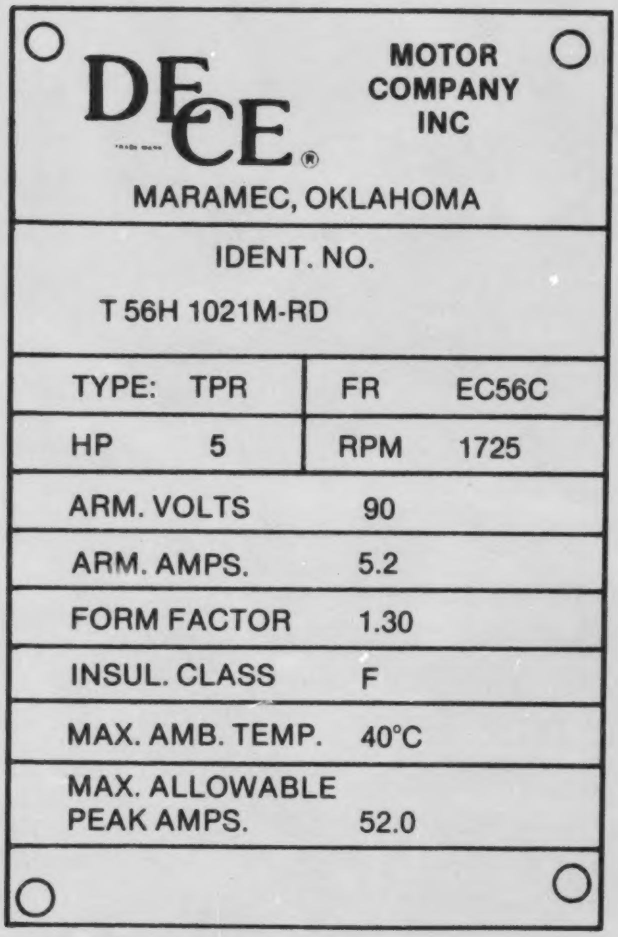

F2
A1
ARM
A2
Series
F1
A1
A2

D. External reversible without interpoles

FIGURE 15


ARM
Series
F1
A1
A2
S1
S2
F2

Typical DC Motor Nameplate



DECE®

MOTOR
COMPANY
INC

MARAMEC, OKLAHOMA

IDENT. NO.

T 56H 1021M-RD

TYPE:	TPR	FR	EC56C
HP	5	RPM	1725

ARM. VOLTS	90
ARM. AMPS.	5.2
FORM FACTOR	1.30
INSUL. CLASS	F
MAX. AMB. TEMP.	40°C
MAX. ALLOWABLE PEAK AMPS.	52.0

DC MOTORS
UNIT I

ASSIGNMENT SHEET #1 — CALCULATE PERCENTAGE OF SPEED REGULATION

NAME ______________________________ SCORE ______________

One step in troubleshooting and repairing a direct current motor properly is calculating percentages of speed regulation.

Use the following formula to find percent of speed regulation, no-load speed, and full-load speed in the following problems. Hand your completed assignment sheet to your instructor for evaluation.

Formula: Percent of Speed Regulation $= \frac{\text{No-Load Speed (NLS) - Full-Load Speed (FLS)}}{\text{No-Load Speed (NLS)}} \times 100$

A. No-load speed is 1,800 rpm; full-load speed is 1,700 rpm. What is the percent of speed regulation?

Speed regulation = ______________%

B. No-load speed is 3,600 rpm, and full-load speed is 3,500 rpm. What is the percent of speed regulation?

Speed regulation = ______________%

ASSIGNMENT SHEET #1

C. Find full-load speed when speed regulation is 3 percent and no-load speed is 3,600 rpm.

Full-load speed = ____________________rpm

D. Find no-load speed when speed regulation is 4.2 percent and full-load speed is 3,400 rpm.

No-load speed = ____________________rpm

DC MOTORS
UNIT I

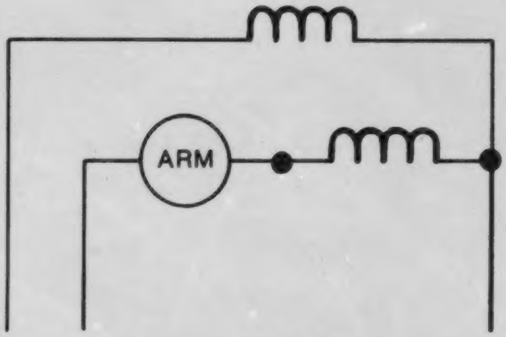
ASSIGNMENT SHEET #2 — LABEL SCHEMATIC DIAGRAMS OF SHUNT, SERIES, AND COMPOUND MOTORS

NAME ______________________________ SCORE ______________

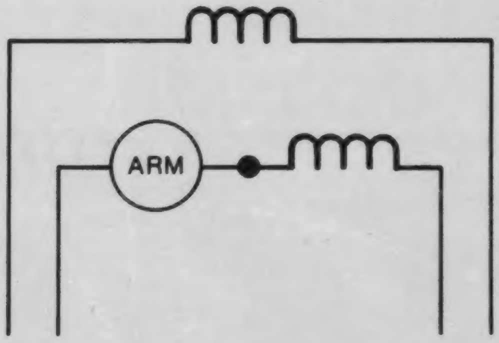
When connecting a direct current motor, technicians must always connect shunt field in parallel with armature, and interpoles in series with armature.

Label the following schematic diagrams. Indicate in the diagrams the correct locations for the armature (A1, A2), shunt field (F1, F2), and series field (S1, S2).

A. Label proper connections and name parts of a nonreversible shunt motor with interpoles.

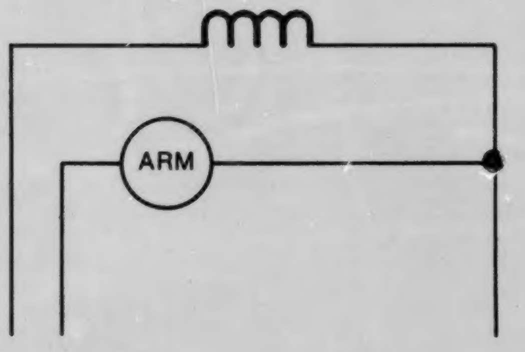


B. Label proper connections and name parts of an external reversible shunt motor with interpoles.

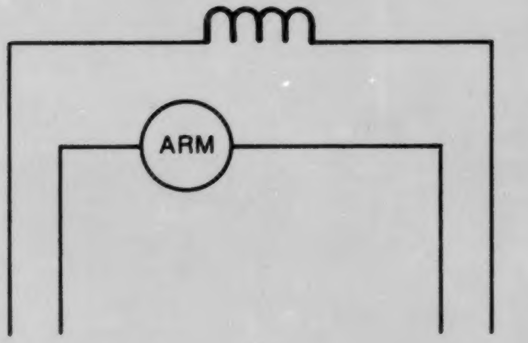


ASSIGNMENT SHEET #2

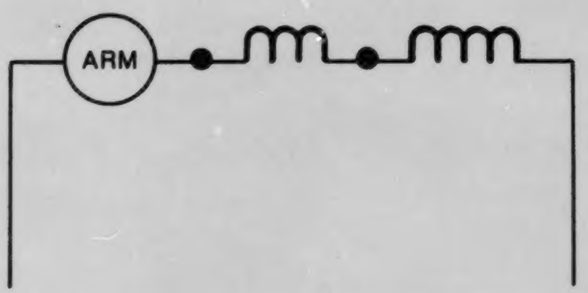
C. Label proper connections and name parts of a nonreversible shunt motor without interpoles.



D. Label proper connections and name parts of an external reversible shunt motor without interpoles.

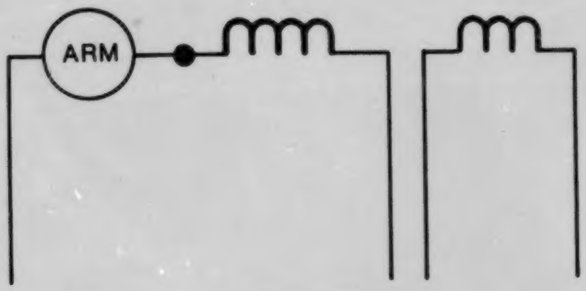


E. Label proper connections and name parts of a nonreversible series motor with interpoles.

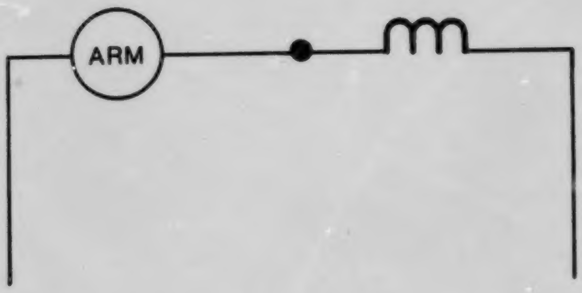


ASSIGNMENT SHEET #2

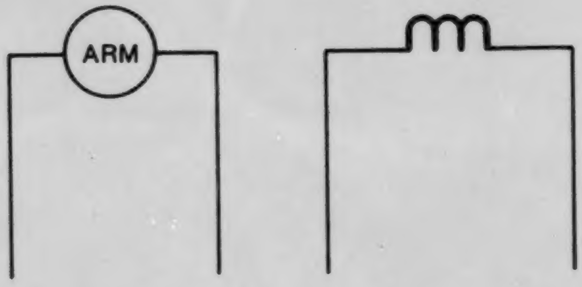
F. Label proper connections and name parts of an external reversible series motor with interpoles.



G. Label proper connections and name parts of a nonreversible series motor without interpoles.

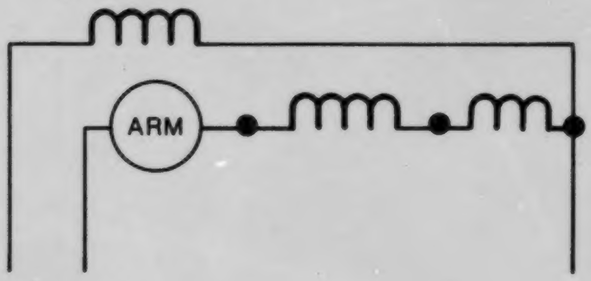


H. Label proper connections and name parts of an external reversible series motor without interpoles.

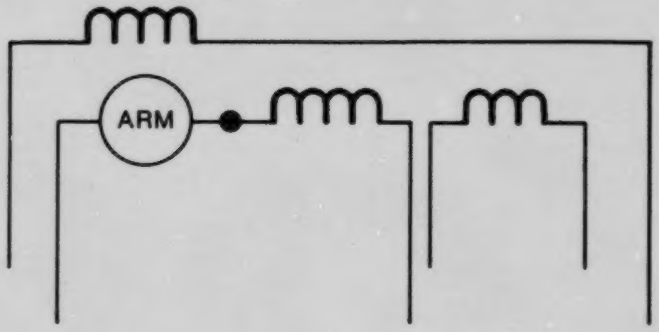


ASSIGNMENT SHEET #2

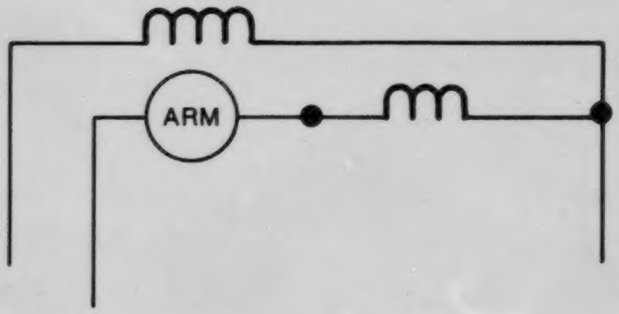
I. Label proper connections and name parts of a nonreversible compound motor with interpoles.



J. Label proper connections and name parts of an external reversible compound motor with interpoles.

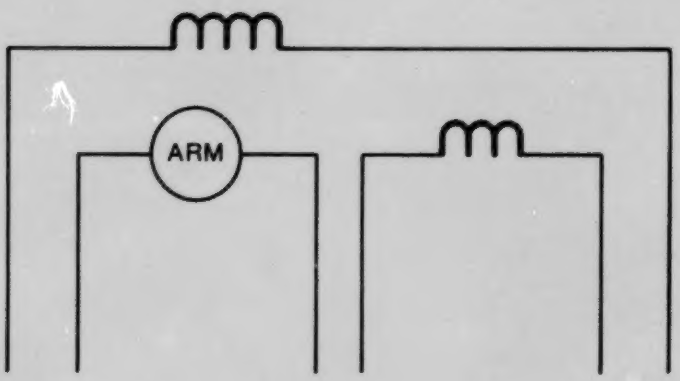


K. Label proper connections and name parts of a nonreversible compound motor without interpoles.



ASSIGNMENT SHEET #2

L. Label proper connections and name parts of an external reversible compound motor without interpoles.



DC MOTORS
UNIT X

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 5.55%

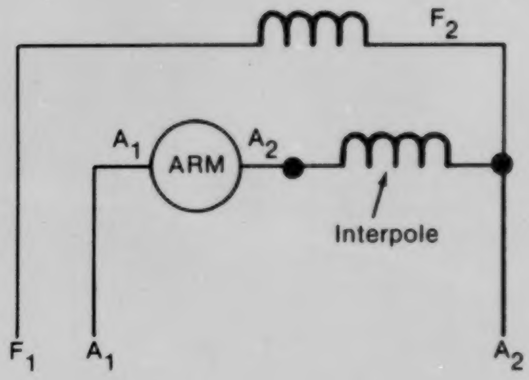
B. 2.77%

C. 3,492 rpm

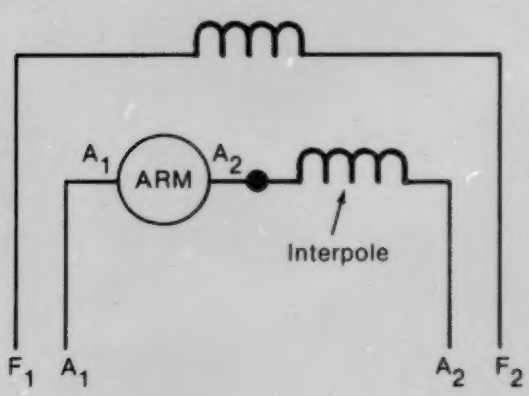
D. 3,549 rpm

Assignment Sheet #2

A.

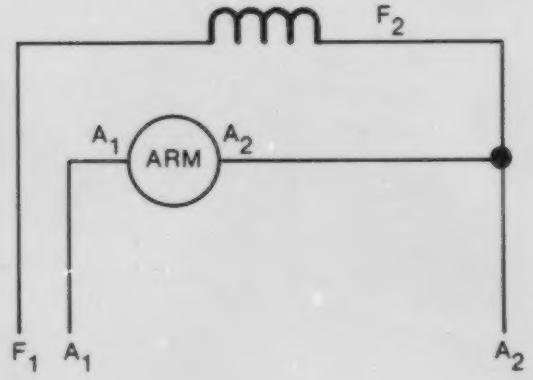

F2
A1
ARM
A2
Interpole
F1
A1
A2

B.

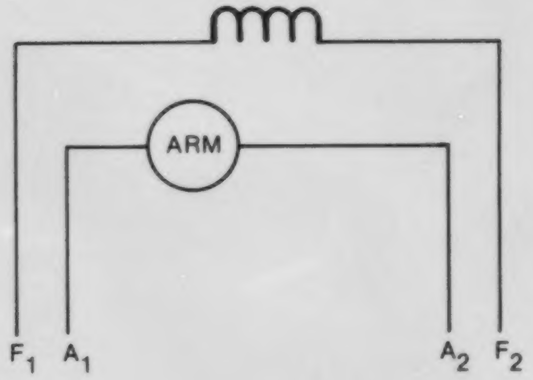

A1
ARM
A2
Interpole
F1
A1
A2
F2

ANSWERS TO ASSIGNMENT SHEETS

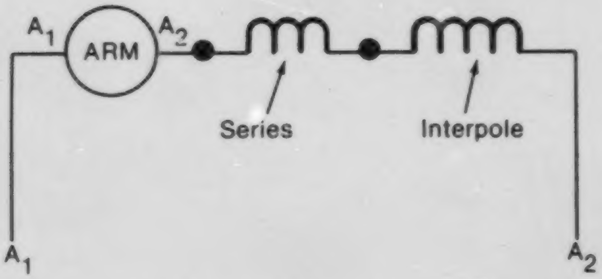
C.


F2
A1
ARM
A2
F1
A1
A2

D.

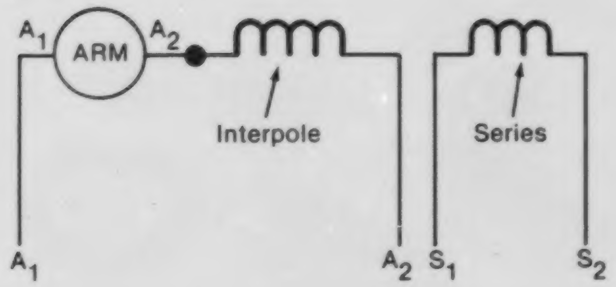

ARM
F1
A1
A2
F2

E.

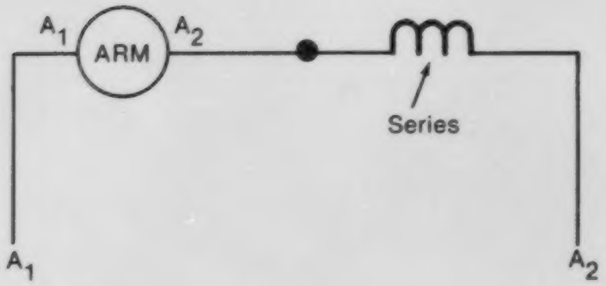

A1
ARM
A2
Series
Interpole
A1
A2

ANSWERS TO ASSIGNMENT SHEETS

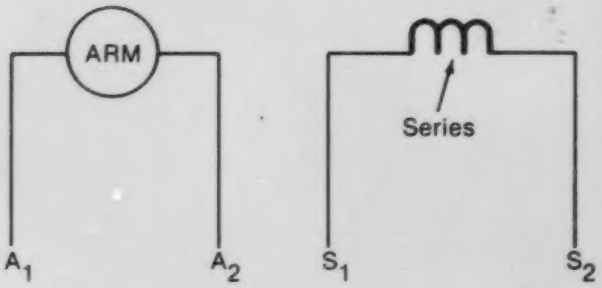
F.


A1
ARM
A2
Interpole
Series
A1
A2
S1
S2

G.

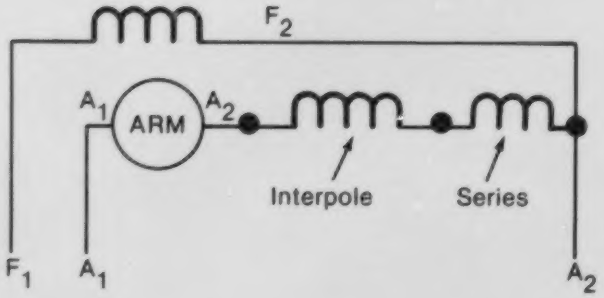

A1
ARM
A2
Series
A1
A2

H.

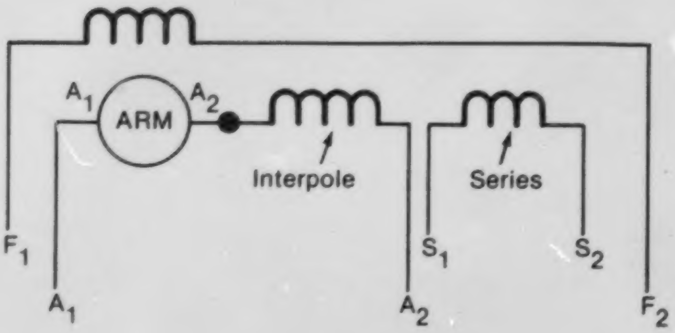

ARM
Series
A1
A2
S1
S2

ANSWERS TO ASSIGNMENT SHEETS

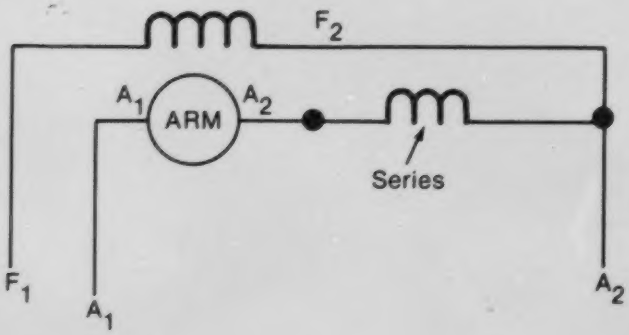
I.


F2
A1
ARM
A2
Interpole
Series
F1
A1
A2

J.

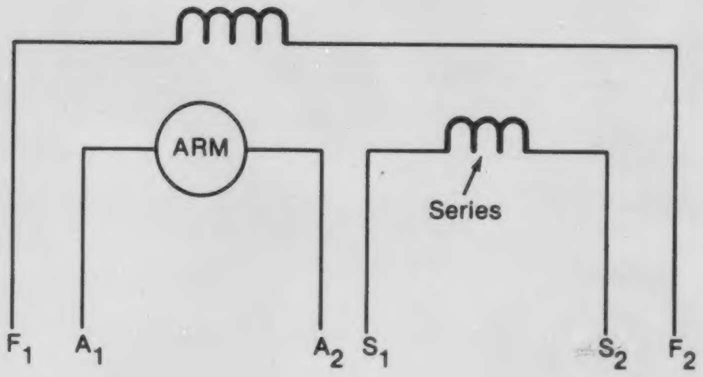

A1
ARM
A2
Interpole
Series
F1
S1
S2
A1
A2
F2

K.


F2
A1
ARM
A2
Series
F1
A1
A2

ANSWERS TO ASSIGNMENT SHEETS

L.


ARM
Series
F1
A1
A2
S1
S2
F2

DC MOTORS
UNIT I

JOB SHEET #1 — USE A STROBOSCOPE AND TACHOMETER TO MEASURE MOTOR SPEED

I. Equipment and materials

A. DC motor

B. Stroboscope

C. Hand tachometer

D. Chalk to mark motor

E. Variable DC power supply

F. Eye protection

II. Procedure

A. Put on eye protection

B. Deenergize motor; check circuit open and lock open

C. Mark the motor shaft to be used for stroboscope and tachometer

D. Plug in the stroboscope to 115 volts AC

E. Adjust stroboscope frequency to approximate speed of motor listed on nameplate

F. Energize motor by slowly increasing output of DC power supply to 125 volts

G. Adjust, read, and record stroboscope speed

rpm = ____________________

H. Hold tachometer on end of shaft

I. Read and record tachometer speed and voltage

rpm = ____________________

volts = ____________________

J. Hold tachometer on end of shaft and adjust voltage until tachometer shows 1,800 rpm

JOB SHEET #1

K. Record speed and voltage

rpm = ____________________

volts = ____________________

L. Hold voltage at the same value and adjust stroboscope for exact revolutions per minute; record speed and voltage

rpm = ____________________

volts = ____________________

(NOTE: The tachometer and stroboscope should read the same revolutions per minute with the same voltage on the motor.)

M. Deenergize motor; check circuit open and lock open

(NOTE: Show work to instructor for evaluation and comments.)

N. Deenergize stroboscope

O. Clean work area; return equipment and materials to their proper places

DC MOTORS
UNIT I

JOB SHEET #2 — USE REVERSE ROTATION TO LOCATE A DIRECT CURRENT MOTOR'S NEUTRAL PLANE

I. Equipment and materials

- A. Socket wrench set
- B. Standard screwdriver set
- C. Combination wrench set
- D. DC ammeter, 0 to 10 ampere range
- E. DC voltmeter with three ranges (0 to 100 volts, 0 to 150 volts, 0 to 300 volts)
- F. Variable DC power supply up to 300 volts direct current
- G. Hand tachometer or stroboscope
- H. DC motor, size to permit use of 10-ampere ammeter
- I. Eye protection

II. Procedure

- A. Put on eye protection
- B. Deenergize motor; check circuit open and lock open
- C. Connect DC ammeter in series with field circuit
- D. Connect DC voltmeter in parallel with field circuit
- E. Loosen brush rigging
- F. Energize motor; observe direction of rotation
- G. Apply full load, using resistance bank or lamps
- H. Measure speed with full load and record

  rpm = ____________________

- I. Check voltage and field current; record

  volts = ____________________

  amps = ____________________

JOB SHEET #2

J. Stop motor and reverse direction of rotation; observe and record as in steps F through I

rpm = ______________________

volts = ______________________

amps = ______________________

(NOTE: If readings are the same in both directions, brushes are in neutral plane, so go to step L.)

K. Shift brushes to direction of original rotation observed at step F

L. Repeat steps F through I, and record all test readings

rpm = ______________________

volts = ______________________

amps = ______________________

(NOTE: Correct position for brushes is one that results in same speed for both directions of rotation.)

M. Tighten brush rigging until no spark occurs in neutral position

N. Deenergize motor; check circuit open and lock open

O. Deenergize ammeter and voltmeter

P. Clean work area; return equipment and materials to their proper places

DC MOTORS
UNIT I

JOB SHEET #3 — DISASSEMBLE, CLEAN, AND REASSEMBLE A MOTOR

I. Equipment and materials

A. DC motor

B. Standard screwdriver set

C. Combination wrench set

D. Vacuum cleaner

E. Center punch

F. Hammer

G. Socket wrench set

H. Soft-faced mallet

I. Nonflammable cleaning fluid

J. Clean rags (lint free)

K. Wheel puller

L. Terminal marking labels

M. Eye protection

II. Procedure

A. Put on eye protection

B. Disconnect motor and remove from mount

(NOTE: Mark leads to assure proper reinstallation.)

C. Clean surface of motor

D. Remove motor pulley

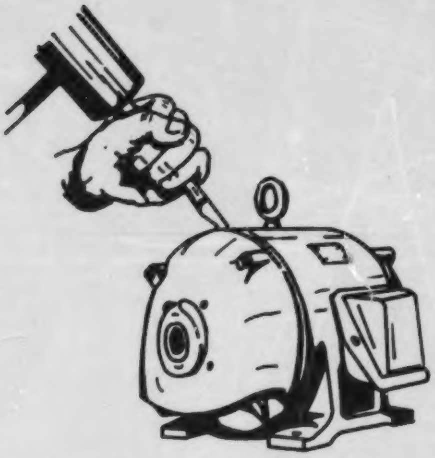
JOB SHEET #3

E. Mark end bells and stator frame (Figure 16)

(NOTE: Marking assures that end bells are returned to their proper positions.)

1. Place one mark on pulley end bell and two marks on opposite end bell, using a center punch
2. Mark stator in the same way
3. Place marks on end bell and stator frame directly across the joint to help align end bells for reinstallation of bolts

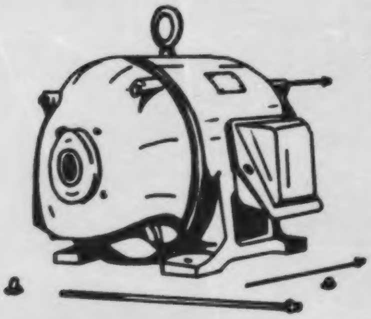
FIGURE 16



F. Check motor for excessive end play before removing end bells

G. Remove bolts holding end bells (Figure 17)

FIGURE 17

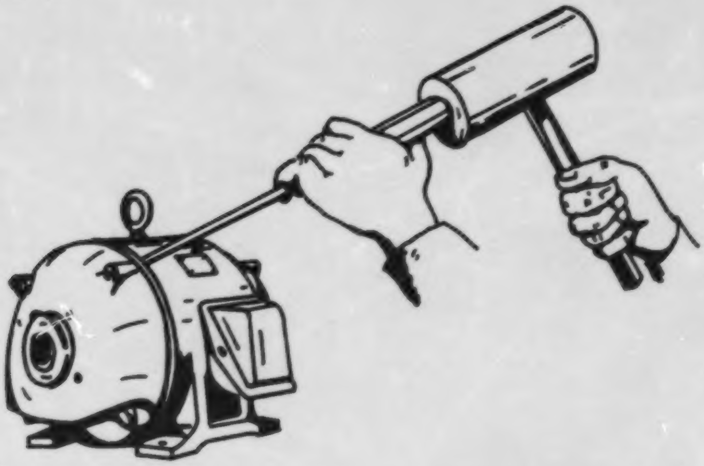


JOB SHEET #3

H. Remove brushes and check for chips and excessive wear

I. Use soft-faced mallet and punch to tap end bells loose (Figure 18)

FIGURE 18



J. Remove end bell that does not contain the brush holders

K. Remove end bell containing brush rigging

L. Remove armature, taking care not to score commutator

(NOTE: Check the number and location of thrust washers.)

M. Clean all parts of motor with nonflammable cleaning fluid

N. Dry parts with vacuum cleaner

O. Check bearings to determine need for replacement or other attention

(NOTE: If bearings do not need to be replaced, clean and lubricate. It is wise to replace sealed bearings while the motor is out of service and disassembled.)

P. Carefully inspect stator windings, wedges, and coil support ties at each end of stator insulation

Q. Make any repairs indicated

R. Replace end bell containing brush rigging

S. Insert armature carefully; make sure that bearings are in place and in good condition, with end play thrust washers in place

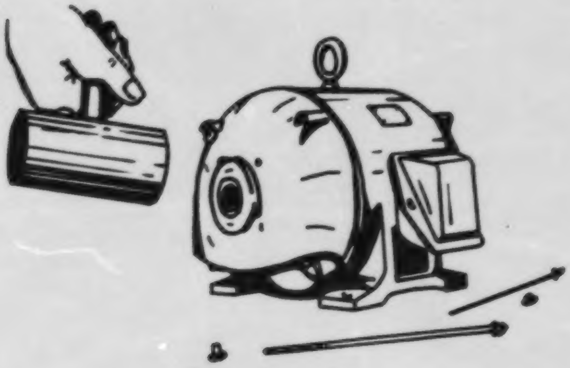
JOB SHEET #3

T. Check position of end bells with center punch markings

U. Align center punch marks

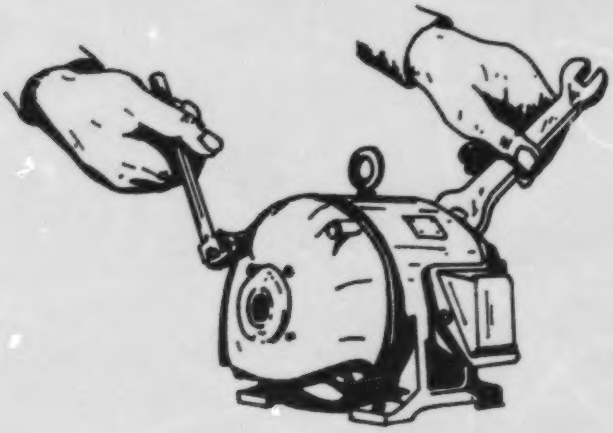
V. Use soft-faced hammer to tap end bells into place (Figure 19)

FIGURE 19



W. Insert end bell bolts and tighten (Figure 20)

FIGURE 20



JOB SHEET #3

X. Turn shaft by hand, rechecking end play

(NOTE: If end play is tight, end bells may not be aligned properly.)

Y. Reinstall brushes

Z. Connect temporary leads; test motor at test bench

(NOTE: Show work to instructor before disconnecting.)

AA. Open switch and lock in open position; check all blades

BB. Clean work area; return equipment and materials to their proper places

DC MOTORS
UNIT I

JOB SHEET #4 — USE A GROWLER TO TEST FOR SHORTS IN A DIRECT CURRENT MOTOR ARMATURE

I. Equipment and materials

- A. Standard screwdriver set
- B. Socket wrench set
- C. Combination wrench set
- D. Hacksaw blade
- E. Growler
- F. DC motor armature
- G. Eye protection
- H. Chalk

II. Procedure

- A. Put on eye protection
- B. Place armature on growler
- C. Lay hacksaw blade flat and lengthwise on armature laminations
- D. Energize growler

  (NOTE: If the hacksaw blade chatters or vibrates, there is a short in the coil.)
- E. Deenergize growler
- F. Rotate armature one-quarter turn and mark with chalk

  (CAUTION: Never rotate armature with growler energized.)
- G. Replace hacksaw blade on armature
- H. Energize growler
- I. Repeat steps E through H twice
- J. Deenergize growler
- K. Clean work area; return equipment and materials to their proper places

DC MOTORS
UNIT I

JOB SHEET #5 — USE A TEST LIGHT TO LOCATE OPENS AND GROUNDS IN A DIRECT CURRENT MOTOR ARMATURE

I. Equipment and materials

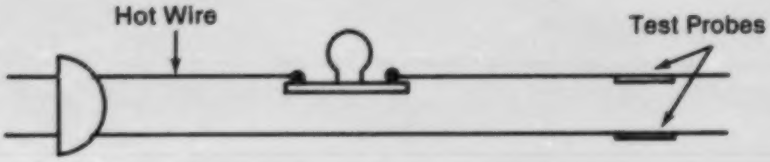
A. Standard screwdriver set

B. Socket wrench set

C. Combination wrench set

D. 120-volt test light setup (Figure 21)

FIGURE 21



E. DC motor armature

F. Eye protection

II. Procedure

A. Put on eye protection

B. Check for opens: inspect visually (very carefully) for signs of arcing between commutator bars

(NOTE: Evidence of arcing is a definite sign of an open coil.)

C. Test for grounds

1. Place armature on insulated table top or dry board

2. Plug in test light

(CAUTION: Live voltages are present at all test probes.)

3. Place neutral test probe on armature laminations

JOB SHEET #5

4. Wipe hot test probe across commutator bars

   (NOTE: If the coils are grounded, the light will burn; if the test light does not burn, the circuit has not been completed and so the coils are not grounded.)

5. Touch the two test probes together to test the test light

6. Unplug test light

   (NOTE: Show work to instructor for evaluation and comments.)

D. Clean work area; return tools and equipment to their proper places

DC MOTORS
UNIT I

JOB SHEET #6 — USE A MEGGER TO CHECK FIELD COILS FOR GROUNDS

I. Equipment and materials

A. 500-volt Megger

B. Clean, dry rags

C. Standard screwdriver set

D. Combination wrench set

E. Pliers

F. Three DC motors

G. Thermometer

II. Procedure

A. Check Megger

(NOTE: With Megger leads in the clear, turn crank; Megger should read infinity. With Megger leads shorted, Megger reads zero.)

B. Connect hot Megger lead to shorted field-winding leads

C. Connect Megger ground lead to motor yoke or frame

D. Crank Megger at about 120 rpm for approximately sixty seconds or until needle settles down

(NOTE: Megger will indicate zero if grounded.)

E. Record Megger reading and ambient temperature at motor

Motor #1

Megger reading = ______________________

Ambient temperature = ______________________

(NOTE: If you find a ground, separate each coil to isolate the coil that is grounded. Test each coil individually.)

F. Plot findings on the chart on the following page

JOB SHEET #6

G. Repeat steps B through F for each remaining motor

Motor #2

Megger reading = ____________________

Ambient temperature = ____________________

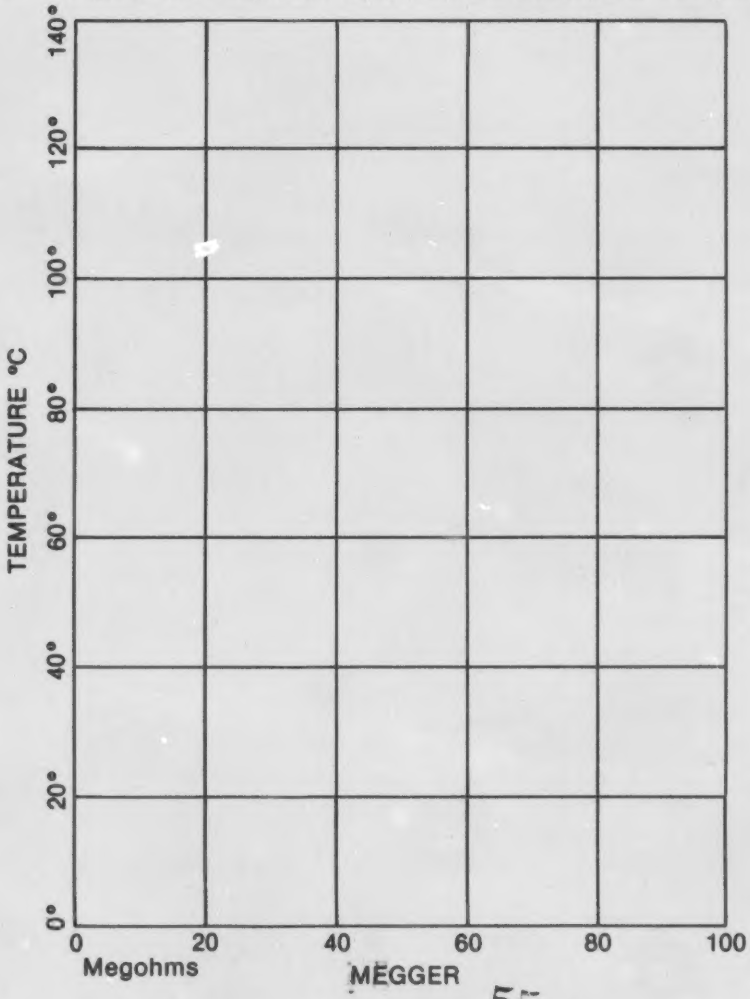
Motor #3

Megger reading = ____________________

Ambient temperature = ____________________

(NOTE: Show work to instructor for evaluation and comments.)

H. Clean work area; return equipment and materials to their proper places



DC MOTORS
UNIT I

JOB SHEET #7 — USE A MULTIMETER TO LOCATE OPENS, SHORTS, AND GROUNDS IN A DIRECT CURRENT MOTOR

I. Equipment and materials

A. Multimeter

B. Knife

C. Standard screwdriver set

D. Pliers

E. Combination wrench set

F. Compound-wound DC motor

II. Procedure

A. Adjust ohmmeter for zero reading on R × 1 scale

(NOTE: Check battery power and zero meter.)

B. Connect meter across motor leads F1 and F2; record resistance readings

Ohms = ____________________

(NOTE: A zero reading indicates shorted coils.)

C. Connect meter across A1 and A2; record resistance readings

Ohms = ____________________

(NOTE: Meter will indicate zero or very close to it.)

D. Connect meter across S1 and S2; record resistance readings

Ohms = ____________________

(NOTE: Meter will have a very low reading, almost zero.)

E. Adjust ohmmeter for zero reading on R × 1,000 scale

F. Connect one meter lead to F1 and other lead to motor frame; record resistance reading

Ohms = ____________________

JOB SHEET #7

G. Connect meter to S1 and motor frame; record resistance reading

Ohms = ____________________

(NOTE: Meter scale should be same as in step E.)

H. Connect meter to A1 and motor frame; record resistance reading

Ohms = ____________________

(NOTE: An indication of ground on A1 could be in armature.)

I. If A1 indicates ground, lift brushes; read again and record resistance reading

Ohms = ____________________

(NOTE: Unrecorded tests are forgotten and worthless tomorrow.)

J. Clean work area; return equipment and materials to their proper places

DC MOTORS
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct definitions terms associated with direct current motors. Write the correct numbers in the blanks. Terms and definitions are continued on the following page.

______a. Electrical pressure or voltage that forces electrical current through a circuit

______b. Generally, the part of an armature used to reverse the direction of current

______c. Rotating part of DC motor that receives electrical energy

______d. Change in motor speed caused by placing external resistance in motor field or armature circuit

______e. Turning, twisting motion produced by interaction of the two magnetic fields

______f. Rotating machine that converts electrical energy into mechanical energy

______g. Number of revolutions a motor will make in sixty seconds

______h. Effect that magnetic field produced by current flow in the armature has on magnetic lines of force produced by field coils

______i. Total of magnetic lines of force existing in any area

______j. Motor in which field coils connect in parallel with armature

______k. Motor's ability to maintain speed when load is applied

______l. Removal of electrical current from a coil in preparation for reversing current

1. Torque
2. Armature
3. Electromotive force (emf)
4. Direct current (DC) motor
5. Speed control
6. Commutator
7. Commutation
8. Shunt motor
9. Speed regulation
10. Revolutions per minute (rpm)
11. Armature reaction
12. Flux

TEST

_____m. Prepared pieces of carbon used to make electrical contact with rotor, commutator, or slip rings to conduct current to rotor coils

_____n. Motor in which field coils connect in series with armature

_____o. Position of brushes that allows speed to remain constant when rotation is reversed

_____p. Current that travels at right angles to the direction of magnetic flux in a metal part; produces unwanted heat

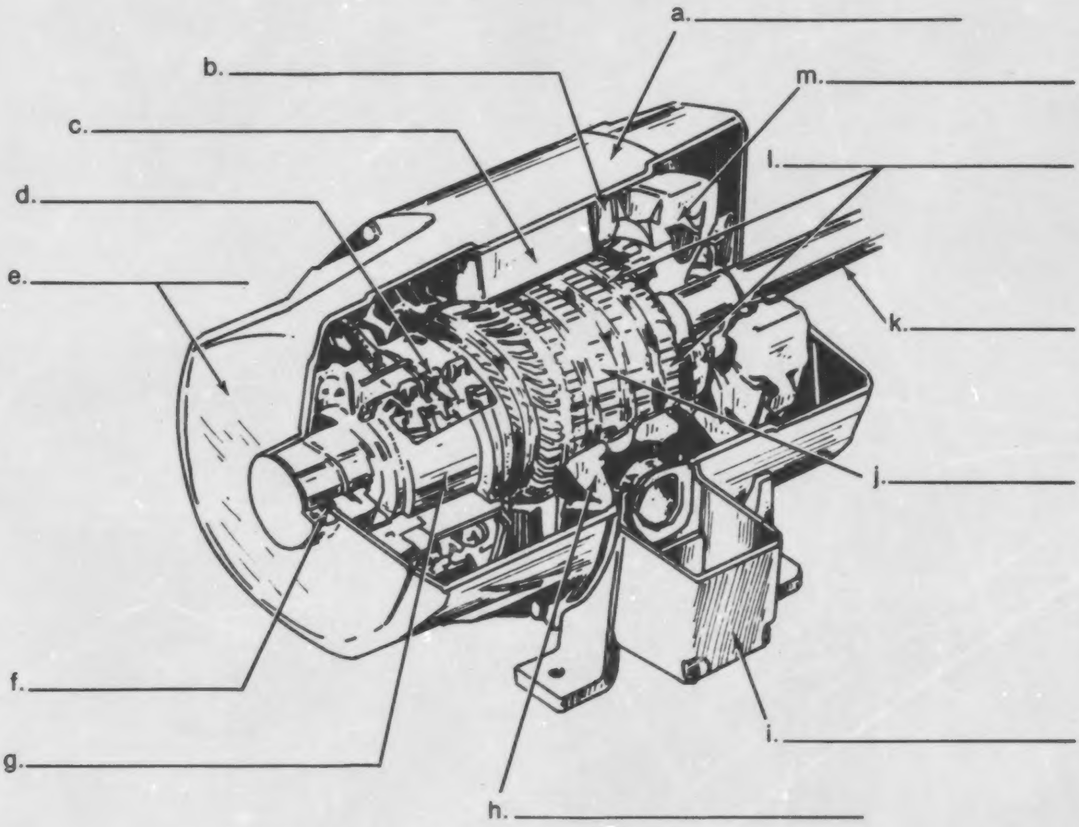
_____q. Lagging of changes in the magnetization of a substance behind changes in the magnetic field as the magnetic field is varied

13. Motor brushes
14. Neutral plane
15. Hysteresis
16. Eddy current
17. Series motor

TEST

2. Identify components of a direct current motor. Write the correct names in the blanks.

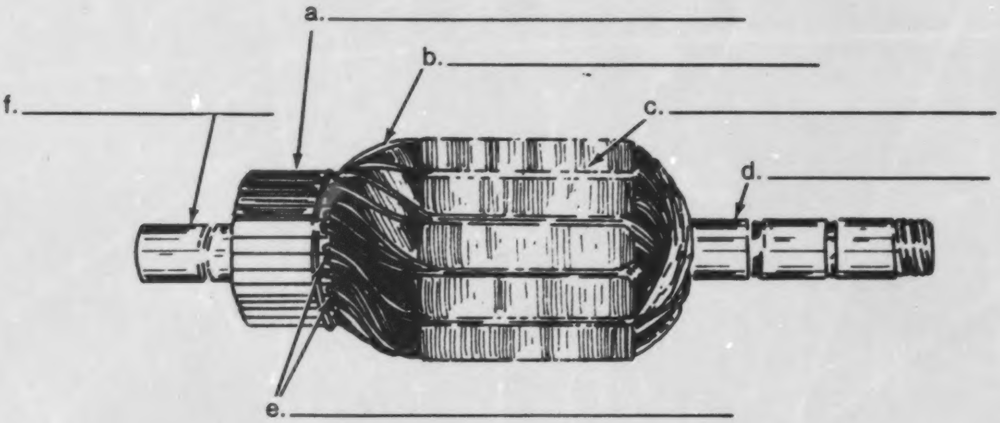
End bell
Field coil
Brush holder and brushes
Armature core
Armature coils
Terminal box
Commutator
Pole piece
Yoke
Shaft
Interpole
Fan
Bearing



TEST

3. Identify the parts of an armature. Write the correct names in the blanks. Answers may be used more than once.

Coils
Shaft
Laminations
Coil ends
Commutator



4. Match direct current motor parts to their correct functions. Write the correct numbers in the blanks. Functions are continued on the next page.

______a. House bearings; support brush rigging; align armature shaft

______b. Carry external current to commutator and coils

______c. Guides brushes on commutator, allows for freedom of movement, and maintains proper spring tension

______d. Support rotating armature; reduce friction for rotating armature

______e. Causes current in armature coils to reverse, causing unlike magnetic poles to face each other; provides surfaces on which brushes ride

______f. Provides mechanical support for pole pieces, core, and end bells; serves as a portion of the magnetic circuit

1. Yoke
2. Pole pieces (field poles)
3. Field coils
4. Armature coils
5. Commutator
6. Brushes
7. Bearings
8. End bells
9. Brush holder

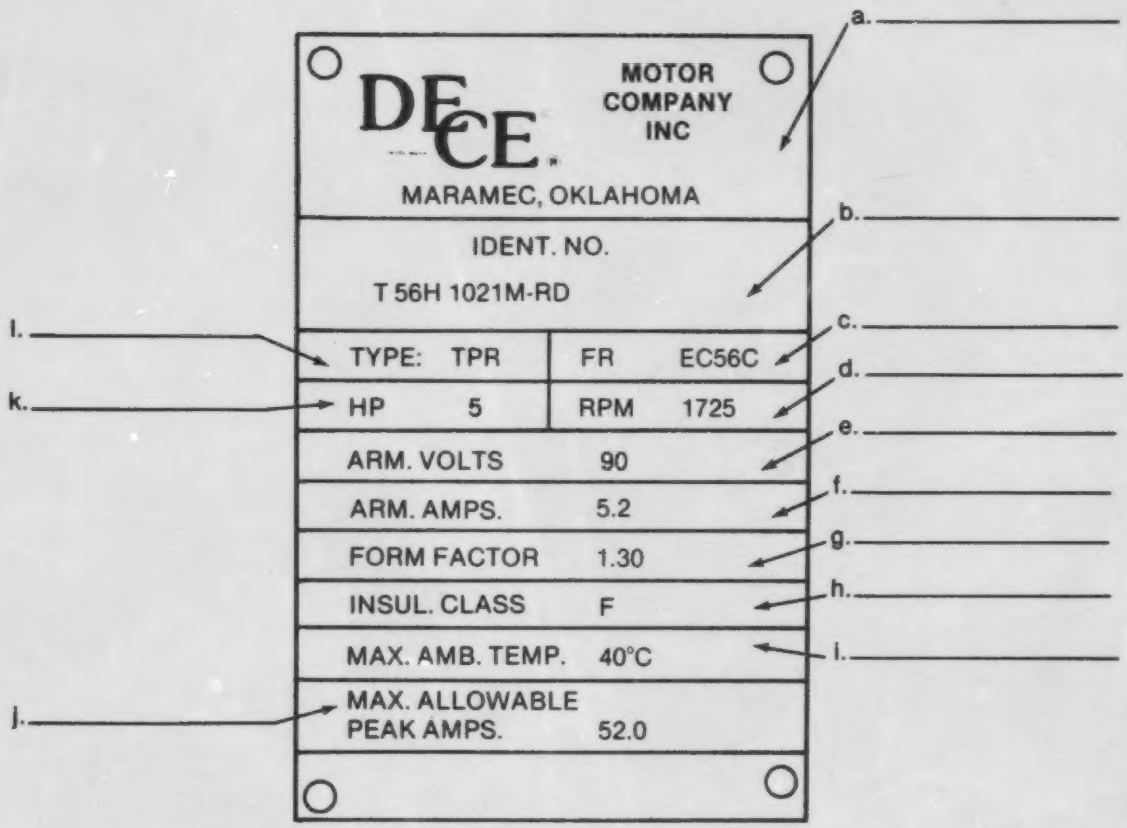
TEST

______g. Support field windings; concentrate magnetic flux

______h. Connect to form alternate north and south magnetic poles; form electromagnets that produce main field flux

______i. Receive electrical energy

5. Label the direct current motor nameplate below.


DECE.
MOTOR COMPANY INC
MARAMEC, OKLAHOMA
IDENT. NO.
T 56H 1021M-RD
TYPE: TPR
FR EC56C
HP 5
RPM 1725
ARM. VOLTS 90
ARM. AMPS. 5.2
FORM FACTOR 1.30
INSUL. CLASS F
MAX. AMB. TEMP. 40°C
MAX. ALLOWABLE PEAK AMPS. 52.0
a. ______
b. ______
c. ______
d. ______
e. ______
f. ______
g. ______
h. ______
i. ______
j. ______
k. ______
l. ______

TEST

6. Select from the following list factors that affect torque. Write an "X" in the blank before each correct answer.

   _____a. Reversed polarity of field windings

   _____b. Bad bearings

   _____c. Reversed armature leads

   _____d. Improper connection of interpoles

   _____e. Reversed series winding leads

   _____f. Reversed brushes

7. State the purpose of commutation.

   ____

   ____

   ____

   ____

   ____

8. Name causes of poor commutation.

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

   f. ____

   g. ____

   h. ____

TEST

9. Calculate percentage of speed regulation in the problem below. Show your work. Use the formula

$$\text{Percent of Speed Regulation} = \frac{\text{NLS} - \text{FLS}}{\text{NLS}} \times 100$$

A DC motor has a no-load speed of 1,800 rpm and a full-load speed of 1,725 rpm. What is the percent of speed regulation?

Speed regulation = ____________________%

10. Select from the following list steps in connecting a shunt motor. Write an "X" in the blank before each correct answer.

_____a. Find directional rotation of motor

_____b. Interpret proper types of connections to be made

_____c. Connect terminals S1 to F1 and S2 to F2

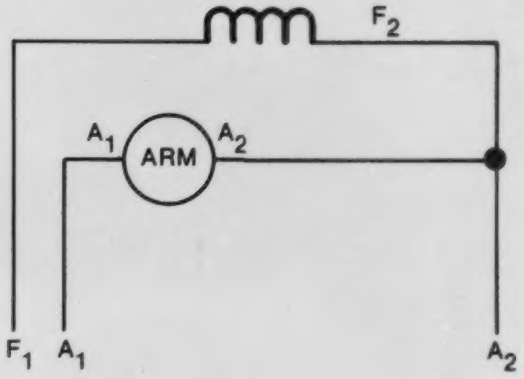
_____d. Identify terminal markings

_____e. Remove end bell

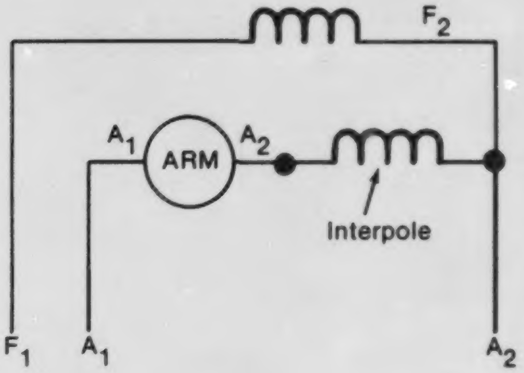
TEST

11. Identify types of shunt motor connections. Write the correct names in the blanks.

Nonreversible with interpoles	**Nonreversible without interpoles**
External reversible with interpoles	**External reversible without interpoles**


F2
A1
ARM
A2
F1
A1
A2

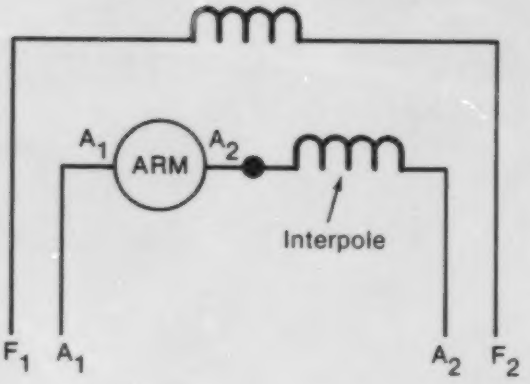
a. ______________________________


F2
A1
ARM
A2
Interpole
F1
A1
A2

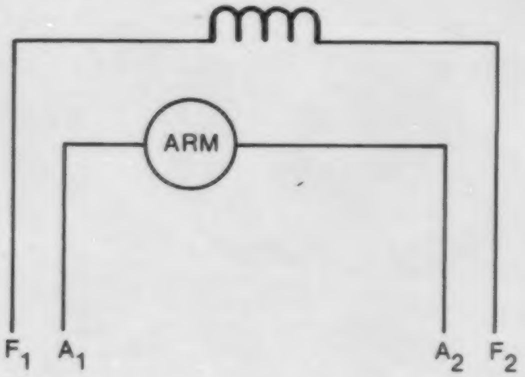
b. ______________________________

2

TEST


A1
ARM
A2
Interpole
F1
A1
A2
F2

c. ______________________________


ARM
F1
A1
A2
F2

d. ______________________________

TEST

12. Select from the following list procedures to avoid when operating a series motor. Write an "X" in the blank before each correct answer.

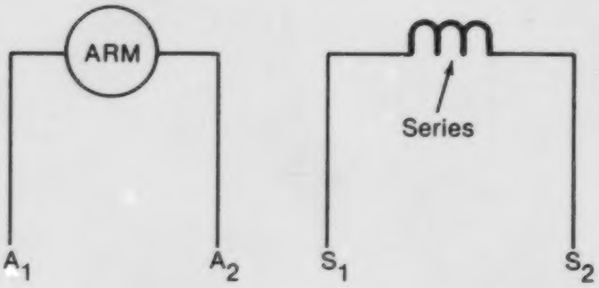
_____a. Never start without a load

_____b. Never use a belt pulley

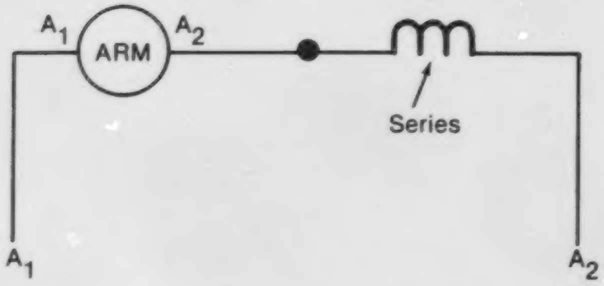
_____c. Never fuse the motor circuit

13. Identify types of series motor connections. Write the correct names in the blanks.

Nonreversible with interpoles	**Nonreversible without interpoles**
External reversible with interpoles	**External reversible without interpoles**

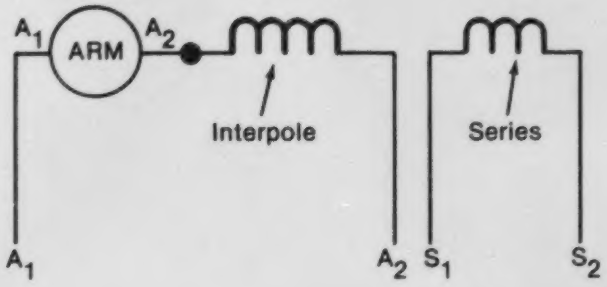


a. ____

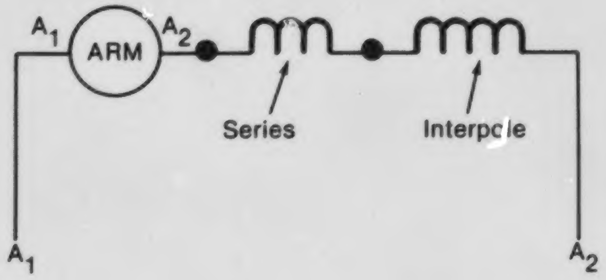


b. ____

TEST


A_1
ARM
A_2
Interpole
Series
A_1
A_2
S_1
S_2

c. ______________________________

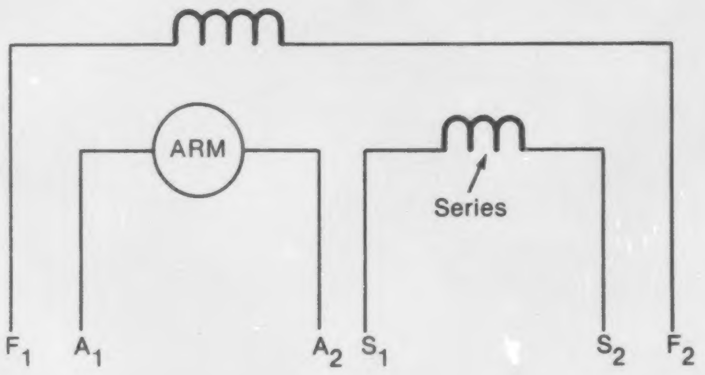

A_1
ARM
A_2
Series
Interpole
A_1
A_2

d. ______________________________

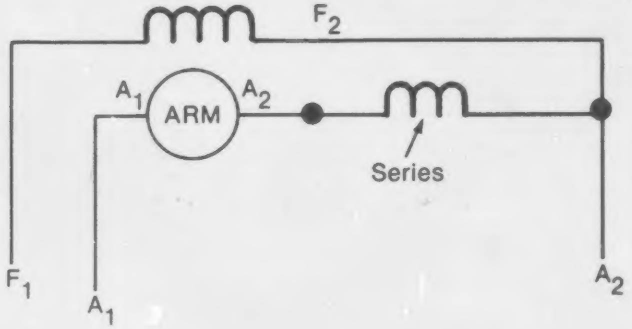
TEST

14. Identify types of compound motor connections. Write the correct names in the blanks.

Nonreversible with interpoles
External reversible with interpoles
Nonreversible without interpoles
External reversible without interpoles

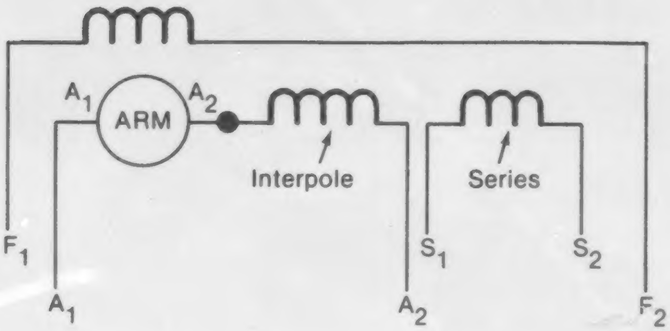

ARM
Series
F_1
A_1
A_2
S_1
S_2
F_2

a. ______________________________

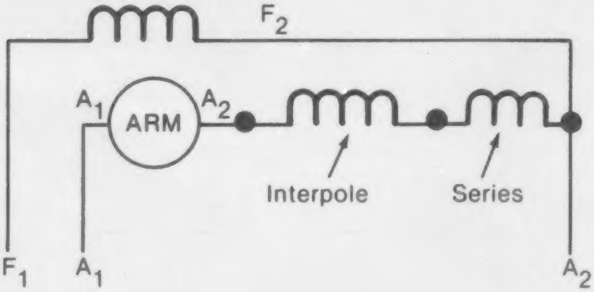

F_2
A_1
ARM
A_2
Series
F_1
A_1
A_2

b. ______________________________

TEST


A1
ARM
A2
Interpole
Series
F1
A1
A2
S1
S2
F2

c. ____


F2
A1
ARM
A2
Interpole
Series
F1
A1
A2

d. ____

(NOTE: Test questions 15 and 16 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

15. Label schematic diagrams of shunt, series, and compound motors.

16. Demonstrate the ability to

    a. Use a stroboscope and tachometer to measure motor speed.

    b. Use reverse rotation to locate a direct current motor's neutral plane.

    c. Disassemble, clean, and reassemble a motor.

    d. Use a growler to test for shorts in a direct current motor armature.

    e. Use a test light to locate opens and grounds in a direct current motor armature.

TEST

f. Use a Megger to check field coils for grounds.

g. Use a multimeter to locate opens, shorts, and grounds in a direct current motor.

DC MOTORS
UNIT I

ANSWERS TO TEST

1. a. 3
   b. 6
   c. 2
   d. 5
   e. 1
   f. 4
   g. 10
   h. 11
   i. 12
   j. 8
   k. 9
   l. 7
   m. 13
   n. 17
   o. 14
   p. 16
   q. 15

2. a. Yoke
   b. Field coil
   c. Pole piece
   d. Brush holder and brushes
   e. End bell
   f. Bearing
   g. Commutator
   h. Interpole
   i. Terminal box
   j. Armature core
   k. Shaft
   l. Armature coils
   m. Fan

3. a. Commutator
   b. Coils
   c. Laminations
   d. Shaft
   e. Coil ends
   f. Shaft

4. a. 8
   b. 6
   c. 9
   d. 7
   e. 5
   f. 1
   g. 2
   h. 3
   i. 4

ANSWERS TO TEST

5. a. Manufacturer
   b. Identification number
   c. Frame
   d. Speed
   e. Voltage
   f. Armature current
   g. Form factor
   h. Insulation class
   i. Ambient temperature
   j. Service factor
   k. Horsepower
   l. Type

6. a, b, c, d, e

7. To maintain unidirectional torque by periodically reversing current in armature conductors as the armature conductors move under alternate poles

8. a. Improper brush pressure
   b. Improper position of brushes
   c. Dirty or rough commutator
   d. Improper brushes
   e. Loose brush rigging and pigtail
   f. High or loose commutator bars
   g. Partially shorted armature
   h. Overloaded motor

9. 4.16%

10. a, b, d

11. a. Nonreversible without interpoles
    b. Nonreversible with interpoles
    c. External reversible with interpoles
    d. External reversible without interpoles

ANSWERS TO TEST

12. a, b

13. a. External reversible without interpoles
    b. Nonreversible without interpoles
    c. External reversible with interpoles
    d. Nonreversible with interpoles

14. a. External reversible without interpoles
    b. Nonreversible without interpoles
    c. External reversible with interpoles
    d. Nonreversible with interpoles

15. Evaluated to the satisfaction of the instructor

16. Performance skills evaluated to the satisfaction of the instructor

DC MOTOR CONTROLS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to test and repair direct current motor controllers and starters. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with direct current motor controls.
2. Label direct current motor schematic symbols.
3. Match abbreviations associated with direct current motor controls to their correct interpretations.
4. Explain the difference between a motor starter and a motor controller.
5. Explain why starting resistance is needed in large direct current motors.
6. Name the classes of motor starters and controllers.
7. Name types of acceleration control provided by motor starters and controllers.
8. Match types of timers to their correct uses.
9. Select from a list characteristics of across-the-line controllers.
10. Describe counter electromotive force in a direct current motor from start to run.
11. Arrange in order the sequence of operation of a counter electromotive force time-limit acceleration starter.
12. Arrange in order the sequence of operation of a voltage-drop current-limit acceleration starter.
13. Explain the purpose of a mechanical interlock on forward and reverse contactors.
14. Arrange in order the sequence of operation of a single-coil series-lockout starter.
15. Arrange in order the sequence of operation of a double-coil series-lockout starter.
16. Arrange in order the sequence of operation of a series relay acceleration starter.

OBJECTIVE SHEET

17. Match methods of electrical braking to their correct descriptions.
18. Select from a list operating characteristics of a series brake.
19. Select from a list operating characteristics of a shunt brake.
20. Draw internal and external connections for a four-point starter and compound motor.
21. Complete a panel wiring diagram of a counter electromotive force motor controller.
22. Complete a panel wiring diagram of a voltage-drop current-limit acceleration controller.
23. Demonstrate the ability to
    a. Connect a manual three-point starter box to a direct current motor.
    b. Connect a three-point starter box and reversing switch in the armature circuit of a shunt motor.
    c. Connect a four-point starter box to shunt motor.
    d. Connect a counter electromotive force controller to a direct current compound motor.
    e. Connect a drum controller to a direct current compound motor.
    f. Use a multimeter and schematic diagram to troubleshoot a direct current controller.

DC MOTOR CONTROLS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Make transparencies.

B. Provide students with objective sheet.

C. Discuss unit and specific objectives. Stress the importance of each objective, and the need for technicians with these abilities.

D. Provide students with information, assignment, and job sheets.

E. Discuss information, assignment, and job sheets.

1. Discuss terms and definitions, using Information Sheet, Section I. When possible, show actual examples to help the students identify the terms with the equivalent pieces of equipment.
2. Discuss symbols used to represent control parts, using Information Sheet, Section II and Transparencies #1 and #2. Refer students to the current IEEE publication of *Graphic Symbols For Electrical and Electronics Diagrams* for additional symbols.
3. Discuss the need for abbreviations of part names and functions, using Information Sheet, Section III. Point out the use of abbreviations throughout the unit as transprarencies are used.
4. Discuss motor starters and controllers, using Information Sheet, Sections IV through VI and Transparencies #3 and #4.
5. Discuss types of acceleration provided by resistor controllers. Use Information Sheet, Section VII. Assignment Sheet #1 allows the students to see how resistance affects the motor's operation in theory. Job Sheets #1 through #3 afford the student practical application.
6. Discuss time-limit acceleration, using Information Sheet, Section VIII and Transparency #5. Use of other timers as models will assist the students in understanding how acceleration can be controlled.
7. Discuss characteristics and horsepower range of across-the-line controllers, using Information Sheet, Section IX and Transparencies #6 and #7.

SUGGESTED ACTIVITIES

8. Discuss counter electromotive force in direct current motors and its use as a current-limiting controller. Use Information Sheet, Sections X through XII. Use Transparency #8 to show steps of operation. Assignment Sheet #2 will familiarize students with wiring counter electromotive force controllers, and Job Sheet #4 will afford the student practical application.

9. Discuss voltage-drop acceleration, using Information Sheet, Section XII and Transparency #9. Use Assignment Sheet #3 to familiarize students with a voltage-drop controller.

10. Discuss single- and double-coil lockout controllers, using Information Sheet, Sections XIII through XV and Transparencies #10 through #13. Show similarities and differences using models of controllers.

11. Discuss series relay controllers, using Information Sheet, Section XVI and Transparencies #14 and #15. Point out similarities and differences between these and series lockout controllers.

12. Discuss operating characteristics of series and shunt brakes, using Information Sheet, Sections XVII through XIX. Point out the need for braking some motors for safety of operation.

13. Demonstrate the connections for a drum controller (Job Sheet #5).

14. Provide schematic diagram for a DC controller and demonstrate standard troubleshooting methods (Job Sheet #6).

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Schematic Symbols

2. TM #2 — Schematic Symbols (Continued)

3. TM #3 — Three- and Four-Point Manual Starters

4. TM #4 — Combination Manual Starter and Speed Controller

5. TM #5 — Control Circuit of Time-Limit Two-Step Acceleration Starter

6. TM #6 — Control Circuit of Simple Across-the-Line Starter

SUGGESTED ACTIVITIES

7. TM #7 — Control Circuit of Across-the-Line Starter with Antiplugging Relay
8. TM #8 — Control Circuit of Counter Electromotive Force Acceleration Starter
9. TM #9 — Control Circuit of Voltage-Drop Current-Limit Acceleration Starter
10. TM #10 — Double-Coil Lockout Relay
11. TM #11 — Control Circuit of Lockout Acceleration Starter
12. TM #12 — Control Circuit of Single-Coil Series-Lockout Starter
13. TM #13 — Control Circuit of Double-Coil Series-Lockout Starter
14. TM #14 — Control Circuit of Individual Dashpot Relay Acceleration Starter
15. TM #15 — Control Circuit of Series Relay Acceleration Starter

E. Assignment sheets

1. Assignment Sheet #1 — Draw Internal and External Connections for a Four-Point Starter and Compound Motor
2. Assignment Sheet #2 — Complete a Panel Wiring Diagram of a Counter Electromotive Force Motor Controller
3. Assignment Sheet #3 — Complete a Panel Wiring Diagram of a Voltage-Drop Current-Limit Acceleration Controller

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Connect a Manual Three-Point Starter Box to a Direct Current Motor
2. Job Sheet #2 — Connect a Three-Point Starter Box and Reversing Switch in the Armature Circuit of a Shunt Motor
3. Job Sheet #3 — Connect a Four-Point Starter Box to a Shunt Motor
4. Job Sheet #4 — Connect a Counter Electromotive Force Controller to a Direct Current Compound Motor

SUGGESTED ACTIVITIES

5. Job Sheet #5 — Connect a Drum Controller to a Direct Current Compound Motor

6. Job Sheet #6 — Use a Multimeter and Schematic Diagram to Troubleshoot a Direct Current Controller

H. Test

I. Answers to test

III. Unit references

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DC MOTOR CONTROLS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Across-the-line starter — Device or switch that starts an electric motor by connecting it directly to the supply line

(NOTE: The across-the-line starter is also called a *full-voltage controller.*)

B. Automatic controller — Motor control mechanism that uses automatic pilot devices such as pressure switches, level switches, or thermostats as activating devices

C. Blowout coil — Electromagnetic coil used in contactors and starters to extinguish or deflect an arc when a circuit is interrupted

D. Compound motor — Direct current motor with two types of field coils: a shunt field coil connected in parallel with the armature, and a series field coil wired in series with the armature

E. Controller — Device for starting a motor in either direction of rotation, or adjusting speed of rotation or torque

F. Current-limit acceleration — Limiting motor acceleration by changes in current brought on by current-sensitive relays

(NOTE: Current-limit acceleration is also called *compensating time.*)

EXAMPLES: Counter electromotive force or voltage-drop acceleration; lockout contactor or series relay acceleration

G. Dashpot — Piston moving inside a cylinder filled with air, oil, mercury, or other fluid (Transparency #14)

(NOTE: Time delay is caused by allowing the air or fluid to escape through a small orifice in the piston; moving contacts actuated by the piston close the electrical circuit.)

H. Drum switch — Controller with electrical connecting parts in the form of fingers held by springs against contacts or surfaces on the perimeter of a rotating cylinder

I. Faceplate controller — Motor starter having a manually controlled wiper arm and several taps, which are contacted by the wiper arm

J. Field accelerating relay — Relay that weakens field-strength in a motor to increase speed after it has started with full-strength field

INFORMATION SHEET

K. Field decelerating relay — Relay that slows down motor as it is pulled into operation by armature current and creates resistance in the motor circuit

L. Interlocks — Small contacts that operate at the same time as the main contacts; govern succeeding operations of the same or allied devices, and may be either electrical or mechanical

M. Lockout — Mechanical device used to control start windings in electric motors; may be set to prevent the operation of a push button (Transparency #11)

N. Low-voltage protection (LVP) — Magnetic control in which service is disconnected automatically as a result of power failure; motor must be manually restarted when power is restored

EXAMPLES: Three- and four-point starters

O. Low-voltage release (LVR) — Magnetic control that automatically disconnects service as a result of power failure; motor automatically restarts when power is restored

EXAMPLE: Series lockout

P. Normally closed contacts — Motor control contacts that are open only while the push button is depressed

Q. Normally open contacts — Motor control contacts that are closed only while the push button is depressed

R. Silicon-controlled rectifier (SCR) — Semiconductor device that blocks voltage applied in either direction; used to control value of armature voltage, and provide a very accurate speed control of DC shunt motors

S. Time-limit acceleration — Starting and bringing a motor up to operating speed in a definite time span regardless of its load

(NOTE: Time-limit acceleration is also known as *definite-time acceleration*.)

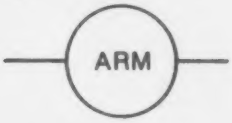
T. Timer — Device that delays closing or opening of a circuit for a specific period of time

INFORMATION SHEET

II. Commonly used direct current motor schematic symbols (Figures 1-21; Transparencies #1 and #2)

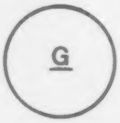
A. Armature

FIGURE 1



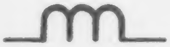
B. DC generator

FIGURE 2



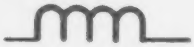
C. Series field

FIGURE 3



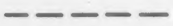
D. Shunt field

FIGURE 4



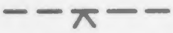
E. Mechanical connection

FIGURE 5



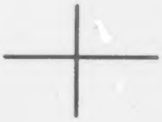
F. Mechanical interlock

FIGURE 6



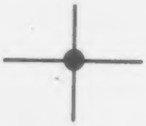
G. Wiring not connected

FIGURE 7



H. Wiring connected

FIGURE 8



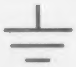
INFORMATION SHEET

I. Wiring terminal

FIGURE 9

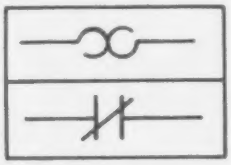
J. Ground

FIGURE 10



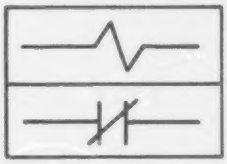
K. Thermal overload relay

FIGURE 11



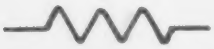
L. Magnetic overload relay

FIGURE 12



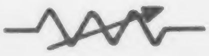
M. Fixed resistor

FIGURE 13



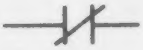
N. Variable resistor

FIGURE 14



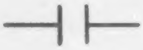
O. Relay with normally closed contacts

FIGURE 15



P. Relay with normally open contacts

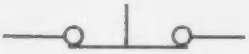
FIGURE 16



INFORMATION SHEET

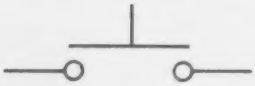
Q. Single-circuit push button, NC

FIGURE 17



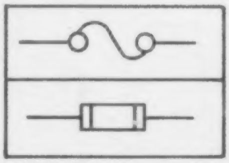
R. Single-circuit push button, NO

FIGURE 18



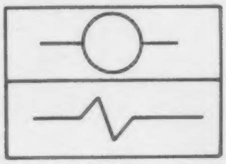
S. Power or control fuse

FIGURE 19



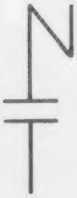
T. Coil

FIGURE 20



U. Blowout coil and contact

FIGURE 21



III. Abbreviations associated with direct current motor controls

A. A — Armature; accelerating contactor

B. F — Shunt field

C. S — Series field

D. L — Terminal line screw connection

E. M — Main line operating coil of contactor

F. T — Terminal lead

G. B — Brake contactor

H. C — Coil or contact

I. UV — Under voltage

INFORMATION SHEET

J. OL — Overload

K. NC — Normally closed

L. NO — Normally open

M. CR — Control relay

N. TR — Time-delay relay

O. AR — Accelerating relay

P. DR — Decelerating relay

Q. VR — Voltage relay

R. SR — Series relay

S. FA — Field accelerating relay

T. AP — Antiplugging

U. HA — Contactor coil for starting resistors

V. TC — Timed closing

W. TO — Timed opening

X. FF — Field failure

Y. PB — Push button

Z. cemf — Counter electromotive force

IV. Difference between a motor starter and a motor controller (Transparencies #3 and #4)

A. Motor starter — Device that limits armature current that flows when motor is first turned on; brings motor safely to its operating speed and is then switched out of circuit

(NOTE: A motor starter is a control, but is only what its name implies, and serves no other function once the motor is brought to operating speed.)

B. Motor controller — Device that combines the functions of a starter and a variable-speed control; starts, stops, reverses, changes speed, or protects motor against overheating

INFORMATION SHEET

V. Why starting resistance is needed in large direct current motors — To reduce the amount of current inrush during the start period so that there is not too great a drain on the power system

VI. Classes of motor starters and controllers

- A. Operation
    - 1. Manual

      EXAMPLES: Faceplate controller, drum controller
    - 2. Automatic

      (NOTE: Automatic controllers may operate from timers, counter electromotive force, or armature current.)
- B. Construction
    - 1. Faceplate
    - 2. Drum
- C. Enclosure type
    - 1. Open
    - 2. Protected

      EXAMPLES: Drip proof, watertight
- D. Number of terminals
    - 1. Two-point
    - 2. Three-point
    - 3. Four-point

      (NOTE: Applying the classification system above, one can have an open, manual, three-point, faceplate starter.)

VII. Types of acceleration control provided by motor starters and controllers (Assignment Sheet #1)

- A. Time
- B. Speed
- C. Current

INFORMATION SHEET

VIII. Types of timers and their uses (Transparency #5)

A. Capacitor — Closes contacts according to voltage potential

EXAMPLE: Capacitor time delay

B. Induction — Delays closing of direct current contacts after circuit is energized

EXAMPLE: Inductive time relay

C. Pneumatic — Forces air through a small hole to delay armature's motion after coil is energized

EXAMPLE: Dashpot timer

D. Electronic — Sets mechanical contacts or triggers solid-state switching device; controlled by a capacitor

(NOTE: Electronic devices have become very popular because of their dependability and relatively low cost and will eventually probably replace other timing devices.)

IX. Characteristics of across-the-line controllers (Transparencies #6 and #7)

A. Do not have starting resistors to limit high current during starting period

B. Motor connected directly across full-line voltage

C. Are used on small direct current motors of 1 horsepower or below

(NOTE: Small DC motors can use the relatively simple across-the-line controller because they have high armature resistance to limit current flow.)

X. Counter electromotive force in a direct current motor from start to run (Transparency #9; Assignment Sheet #2)

(NOTE: Kirchoff's voltage law states that the algebraic sum of all voltages in any complete electrical circuit equals zero.)

A. The motor's counter electromotive force is zero at the moment the motor is started

B. The only voltage drop in the armature (0 to 10 ohms) is caused by the resistance of the armature

INFORMATION SHEET

C. The motor's counter electromotive force increases as the motor accelerates

(NOTE: Counter electromotive force is generated with a polarity opposite to the applied voltage.)

XI. Sequence of operation of a counter electromotive force time-limit acceleration starter (Transparency #8; Assignment Sheet #1)

A. The moment the start button is pushed, counter electromotive force equals zero

(NOTE: At the instant of start, there is a very small voltage drop across the armature (0 to 10 ohms), but it is not enough to cause the relay to pull in.)

B. As the motor accelerates, counter electromotive force builds up in the armature

C. The voltage drop across the armature increases with speed until the relay coil of the acceleration circuit is strong enough to pull in, closing its contacts and shorting out the starting resistors

D. The acceleration circuit is set to operate at a current value that corresponds to 100 percent of the full-load current

(NOTE: Counter electromotive force controllers are generally used on motors that are below 3 horsepower.)

XII. Sequence of operation of a voltage-drop current-limit acceleration starter (Transparency #9; Assignment Sheet #3)

A. When the start button is depressed, the M contact closes

B. The high starting current causes a voltage drop across the starting resistors, which allows relay HA to hold against the pull of relay A1, permitting the motor to accelerate with the starting resistor in series with the armature

C. As the motor gains speed, current through the armature circuit decreases, and the voltage drop across the starting resistors decreases

D. When the voltage drop across the starting resistors decreases to a predetermined value, contactors A1, A2, and A3 outpull the HA relays in sequence

E. Closing contactors A1, A2, and A3 then close main contacts A1, A2, and A3 in sequence, connecting the motor directly across the line

XIII. Purpose of a mechanical interlock on forward and reverse contactors — To prevent both the forward and reverse coils from being energized simultaneously

INFORMATION SHEET

XIV. Sequence of operation of a single-coil series-lockout starter (Transparencies #12 and #13)

(NOTE: There are several other types of single-coil lockout contactors, but all operate on the same principle of magnetic difference between two points. This method of current-limit acceleration depends on the current flow through the armature circuit. Transparencies #14 and #15 show steps of resistance in lockout and series-lockout starters.

A. Start button is depressed

B. Main contacts close and circuit is formed from positive line through lockout coil, resistance, and armature circuit to negative line

C. After initial high current has decreased and motor has accelerated, current through coil permits accelerating contacts A1, A2, and A3 to close, cutting out resistance

D. Current then goes through lockout coil and armature circuit to negative line or L2

XV. Sequence of operation of a double-coil series-lockout starter (Transparencies #10 and #13)

A. Start button is depressed

B. M coil is energized, closing M contacts and putting armature and series field in series with starting resistors and contactors A1 and HA1

C. A1 contactor closes A1 contact, cutting out R1 resistor

D. A2 and HA2 contactors close A2 contact and cut out R2 resistor

E. A3 and HA3 contactors close A3 contact and cut out R3 resistor

F. Armature in series field is directly across the line

XVI. Sequence of operation of a series relay acceleration starter (Transparencies #14 and #15)

A. Start button is depressed

B. M coil is energized, closing M contacts and putting armature and series field in series with starting resistors and A1 contactor

C. A1 coil is energized, completing the circuit through SR1, closing A1 contacts, and cutting out R1 resistor

INFORMATION SHEET

D. A2 coil is energized, completing the circuit through SR2, closing A2 contacts, and cutting out R2 resistor

E. SR3 to A3 coil is energized, closing A3 contacts and cutting out R3 resistor

F. Armature in series field is directly across the line and, based on load attached to motor, accelerates to a normal speed

XVII. Methods of electrical braking

A. Regenerative — Energy of inertia and gravity causes motor to act as generator and retards or stops motor; power generated can be fed back into circuit

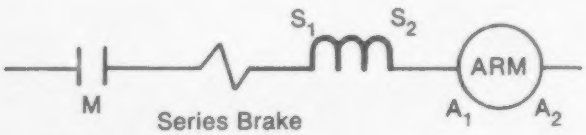
B. Dynamic — Motor used like generator stops the revolving stator field; an energy-dissipating resistor is applied to the armature

C. Plug — Line voltage or phase sequence is reversed; motor develops retarding force

XVIII. Operating characteristics of a series brake (Figure 22)

(NOTE: Series-wound brakes are generally used with series motors and must have the same full-load current rating as the motor. Series brakes are used for heavy hoist applications such as steel mill drives and conveyors.)

FIGURE 22



A. Will release at 40 percent of full-load armature current if designed for intermittent duty

B. Will release at 80 percent of full-load armature current if designed for continuous duty

C. Needs 10 percent of full-load armature current to maintain brake release

D. Has spring that mechanically sets brake

E. Provides fast operation and positive braking action if armature circuit becomes open

F. Is large and may not release if current through series coil is not high enough

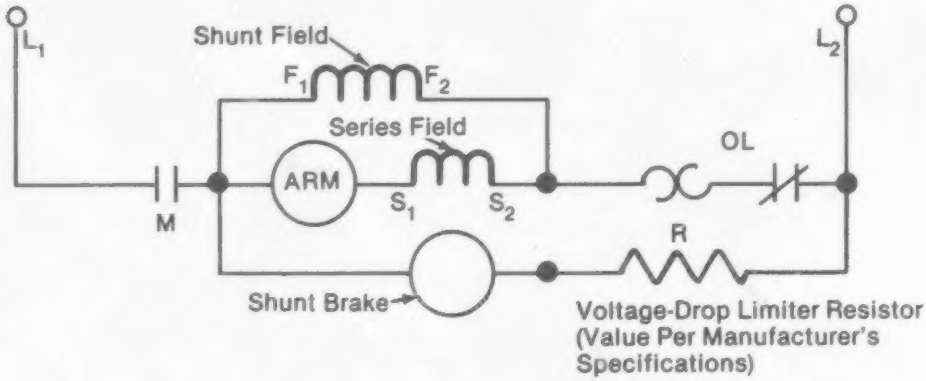
(NOTE: Total armature current is determined by the current through the armature. Light loads may not draw enough current.)

INFORMATION SHEET

XIX. Operating characteristics of a shunt brake (Figure 23)

(NOTE: Shunt brakes range in size from 1 inch to 30 inches in diameter. The large-diameter, high-speed brakes release quickly and are suitable for any duty.)

FIGURE 23


L1
Shunt Field
F1
F2
L2
Series Field
OL
ARM
M
S1
S2
R
Shunt Brake
Voltage-Drop Limiter Resistor (Value Per Manufacturer's Specifications)

A. Coils are wound for one-tenth to one-half of line voltage to increase its operating speed

(NOTE: A resistor is placed in series with the coil to limit voltage. The voltage-drop resistor is available in large-diameter shunt-wound brakes, and permits operation at high speed. When the resistor is inserted in the circuit, the holding current is reduced to a low value and keeps the coil cooler. As a result, the shunt brake with the voltage-drop limiter resistor sets quickly.)

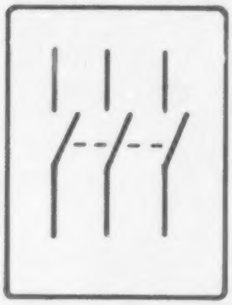
B. Releases at approximately 80 percent of line voltage

C. Is used more often than series brake because it is more effective on widely varying and light loads

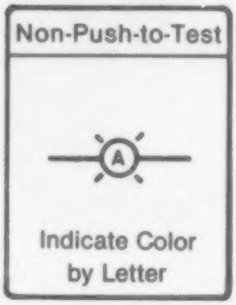
D. Is slow-acting due to high inductance of shunt coil

Schematic Symbols

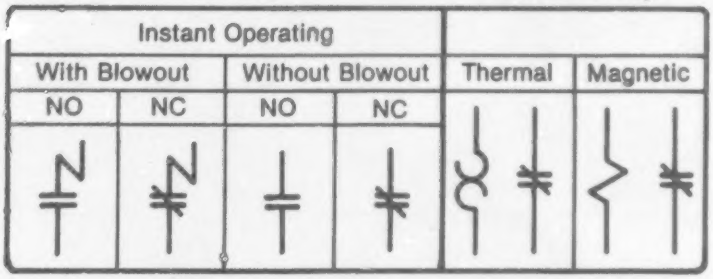
Disconnect



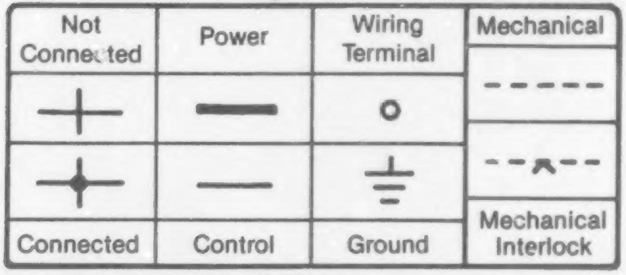
Pilot Light


Non-Push-to-Test
A
Indicate Color by Letter

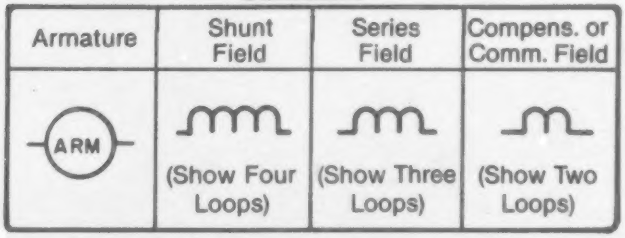
Contacts **Overload Relays**


Instant Operating
With Blowout
Without Blowout
NO
NC
NO
NC
Thermal
Magnetic

Wiring **Connections**


Not Connected
Power
Wiring Terminal
Mechanical
Connected
Control
Ground
Mechanical Interlock

DC Motors

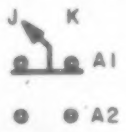

Armature
Shunt Field
Series Field
Compens. or Comm. Field
ARM
(Show Four Loops)
(Show Three Loops)
(Show Two Loops)

Source: *Electrical Motor Controls* by Gary Rockis and Glen Mazur, 1982, American Technical Publishers, Inc.

Schematic Symbols
(Continued)

Selectors

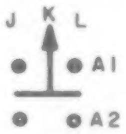
Two Position



	J	K
A1	X	
A2		X

X-Contact Closed

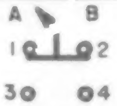
Three Position



	J	K	L
A1	X		
A2			X

X-Contact Closed

Two-Position Push Button



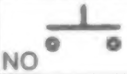
CONTACTS	Selector Position			
	A		B	
	Button		Button	
	Free	Depres'd	Free	Depres'd
1 – 2	X			
3 – 4		X	X	X

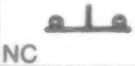
X-Contact Closed

Push Buttons

Momentary Contact

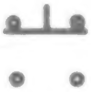
Single Circuit



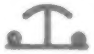


Double Circuit

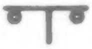
NO & NC



Mushroom Head

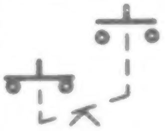


Wobble Stick

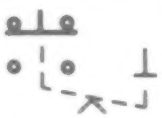


Maintained Contact

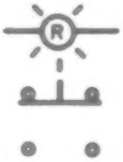
Two Single Circuit



One Double Circuit

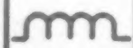


Illuminated

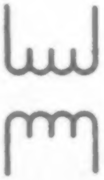


Transformers

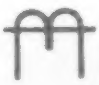
Auto



Air Core

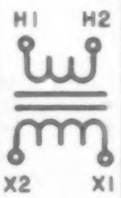


Current

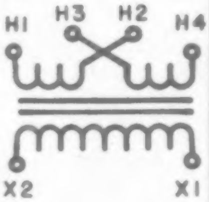


Control Transformer

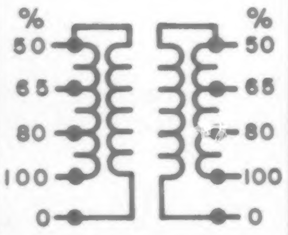
Single Voltage



Dual Voltage

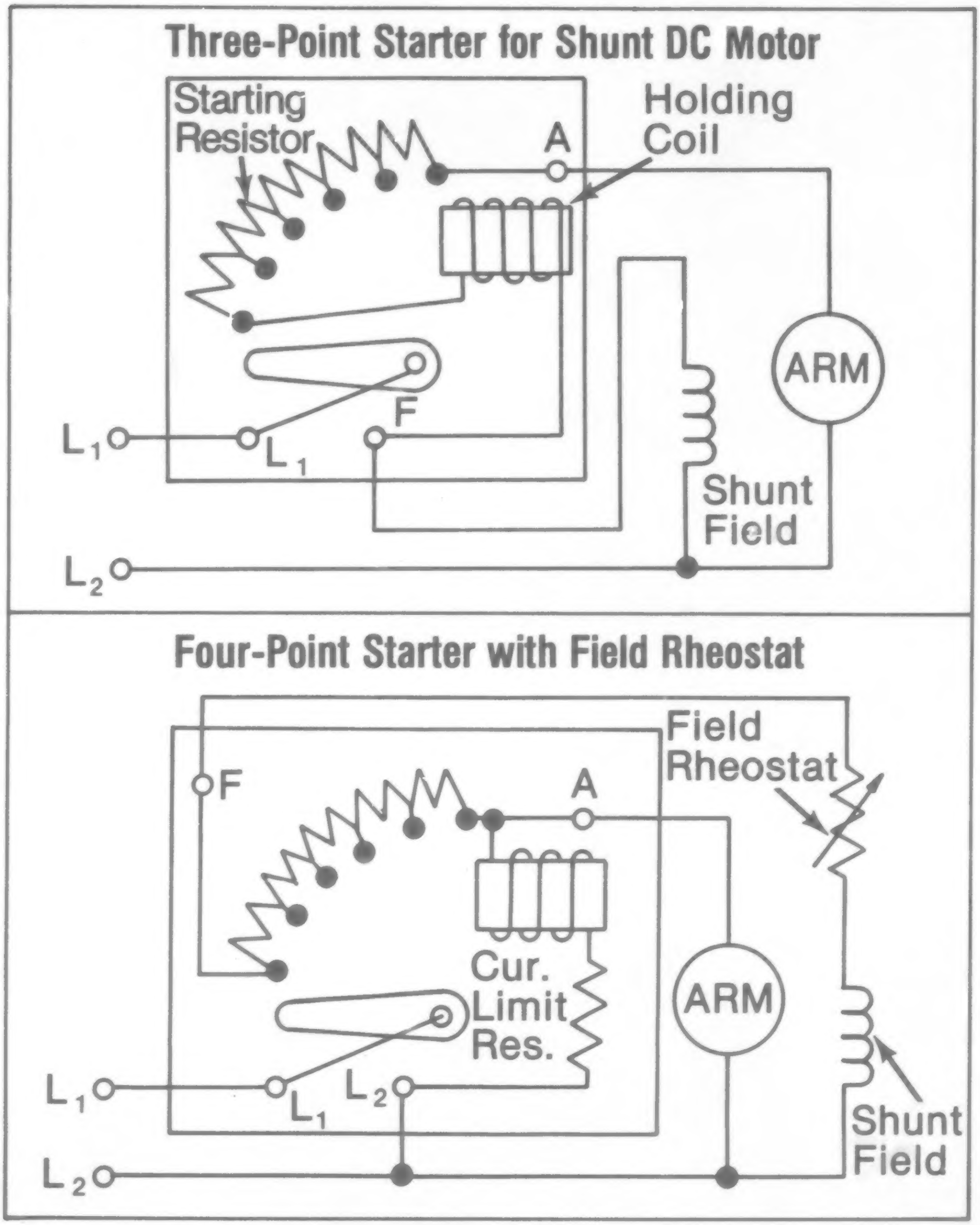

H1
H3
H2
H4
X2
X1

Automatic Transformer for Reduced-Voltage Starting

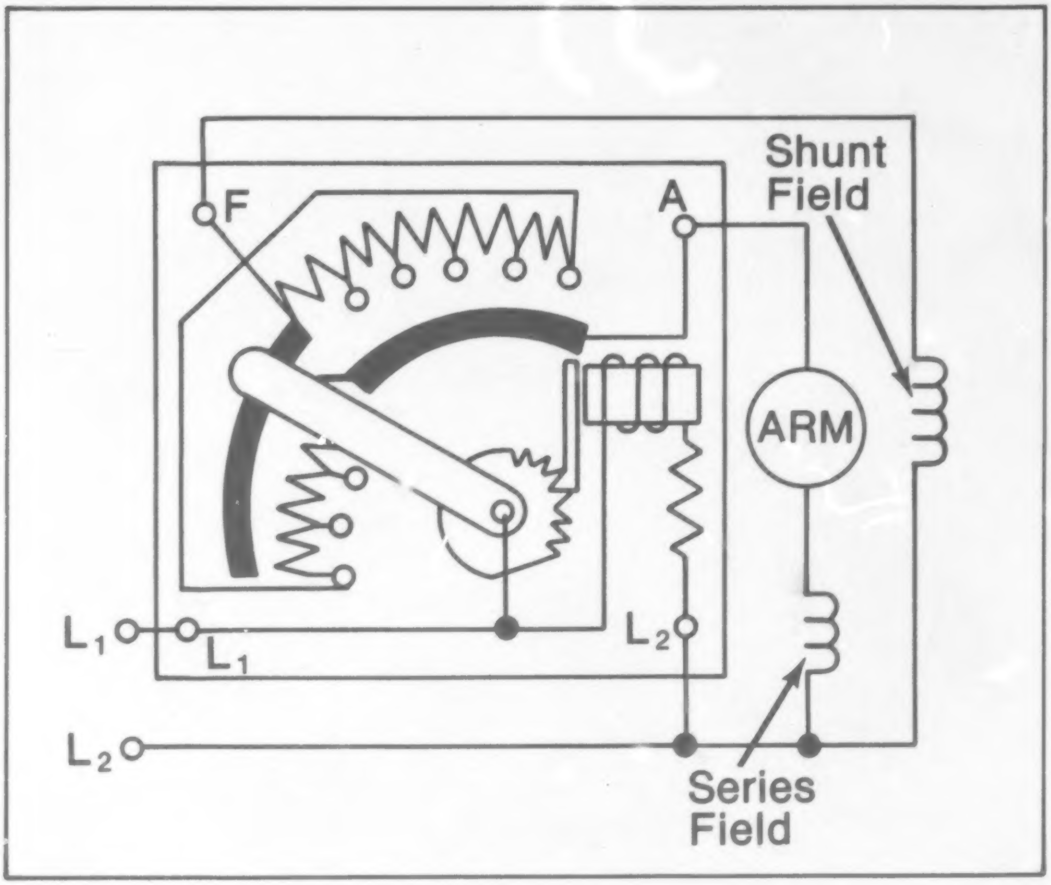

%
50
65
80
100
0
%
50
65
80
100
0

Source: *Electrical Motor Controls* by Gary Rockis and Glen Mazur, 1982, American Technical Publishers, Inc.

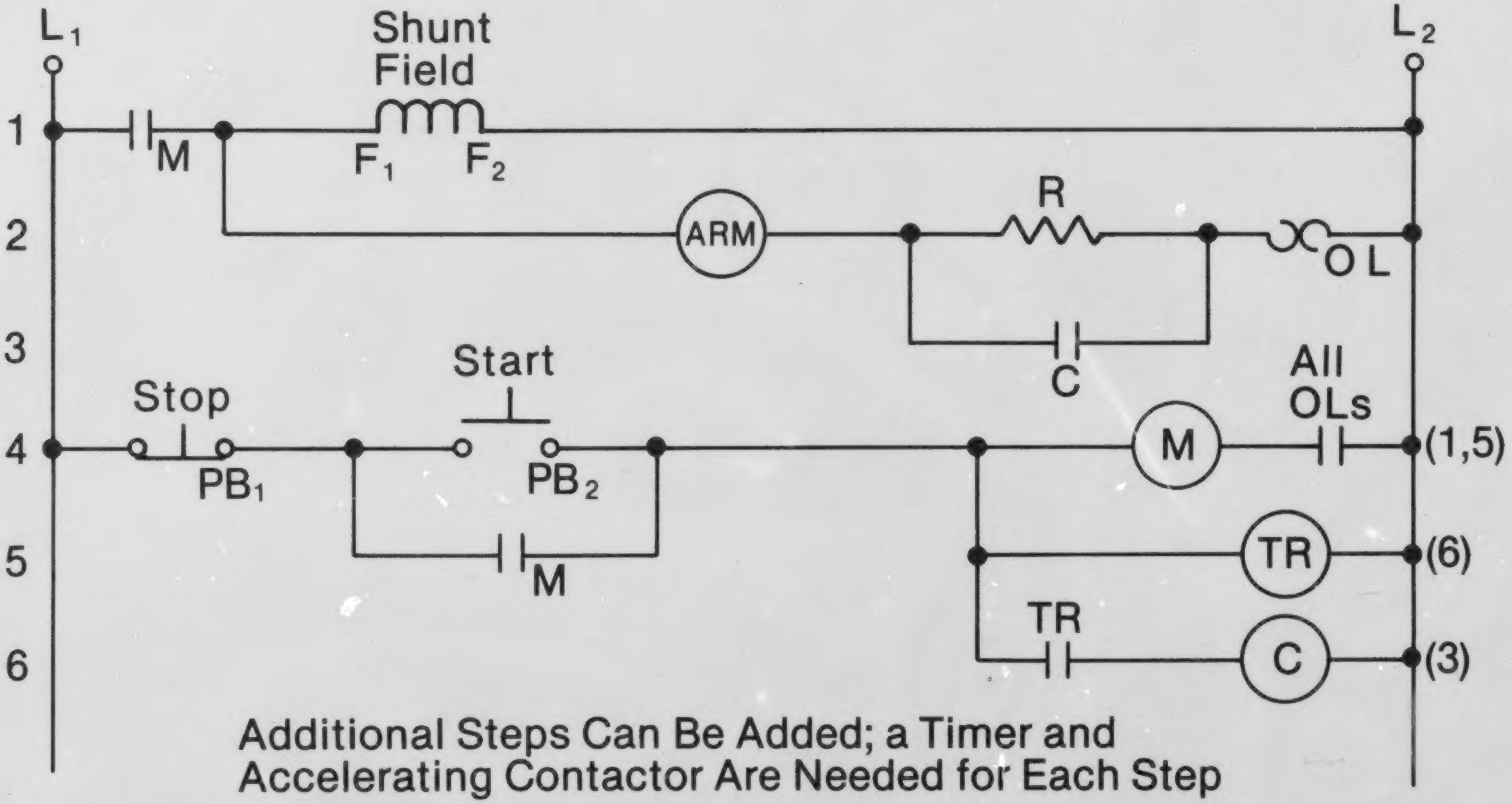
Three- and Four-Point Manual Starters


Three-Point Starter for Shunt DC Motor
Starting Resistor
Holding Coil
A
ARM
F
L_1
L_1
Shunt Field
L_2
Four-Point Starter with Field Rheostat
Field Rheostat
F
A
Cur. Limit Res.
ARM
L_1
L_1
L_2
L_2
Shunt Field

Combination Manual Starter and Speed Controller

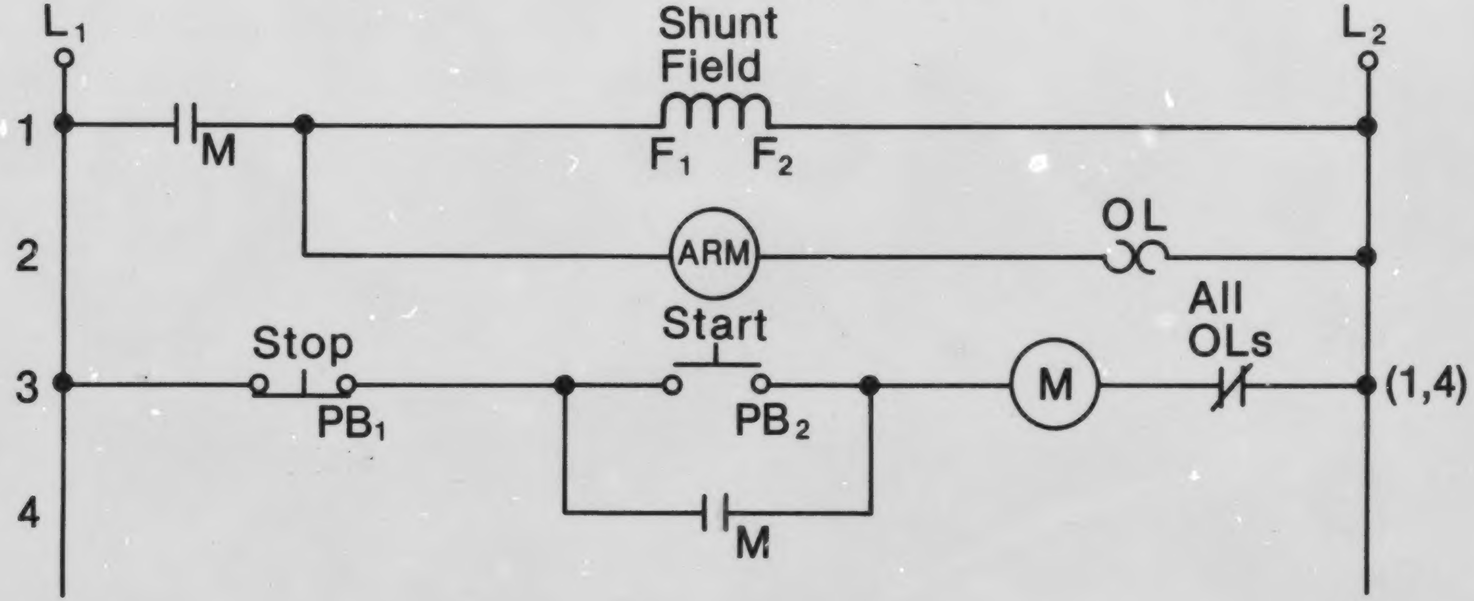

F
A
Shunt Field
ARM
L_1
L_1
L_2
L_2
Series Field

Control Circuit of Time-Limit Two-Step Acceleration Starter

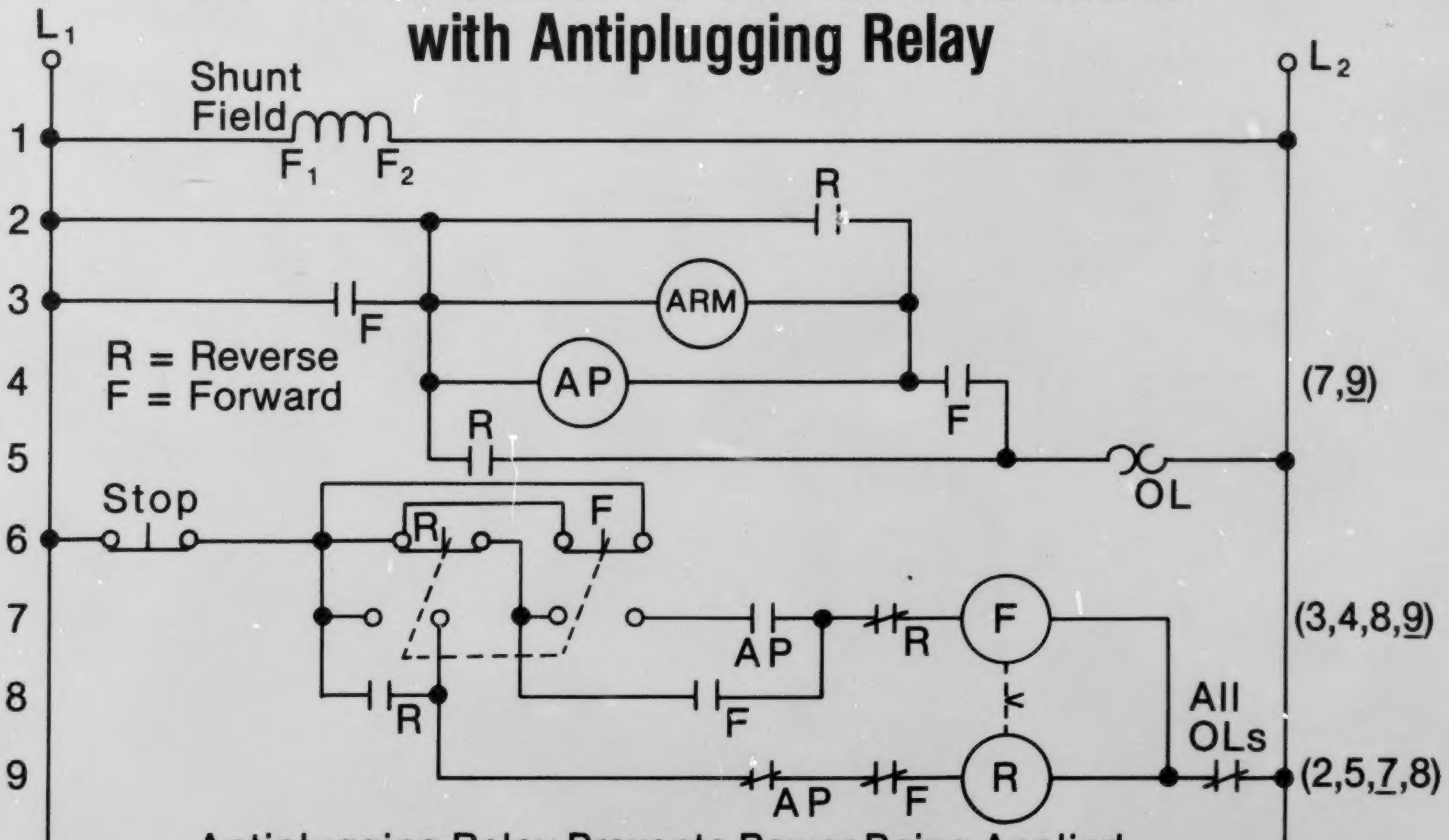

L$_1$
L$_2$
Shunt Field
1
M
F$_1$
F$_2$
2
ARM
R
OL
3
C
Start
Stop
All OLs
4
PB$_1$
PB$_2$
M
(1,5)
5
M
TR
(6)
6
TR
C
(3)

Additional Steps Can Be Added; a Timer and Accelerating Contactor Are Needed for Each Step

Control Circuit of Simple Across-the-Line Starter


L₁
L₂
Shunt Field
1
M
F₁
F₂
2
ARM
OL
3
Stop
Start
All OLs
PB₁
PB₂
M
(1,4)
4
M

Control Circuit of Across-the-Line Starter with Antiplugging Relay



L1
L2
Shunt Field
F1
F2
1
2
3
4
5
6
7
8
9
R
F
ARM
AP
R
F
R = Reverse
F = Forward
OL
Stop
R
F
AP
R
F
R
F
All OLs
AP
F
R
(7,9)
(3,4,8,9)
(2,5,7,8)

Antiplugging Relay Prevents Power Being Applied While Motor Is Running Full Speed

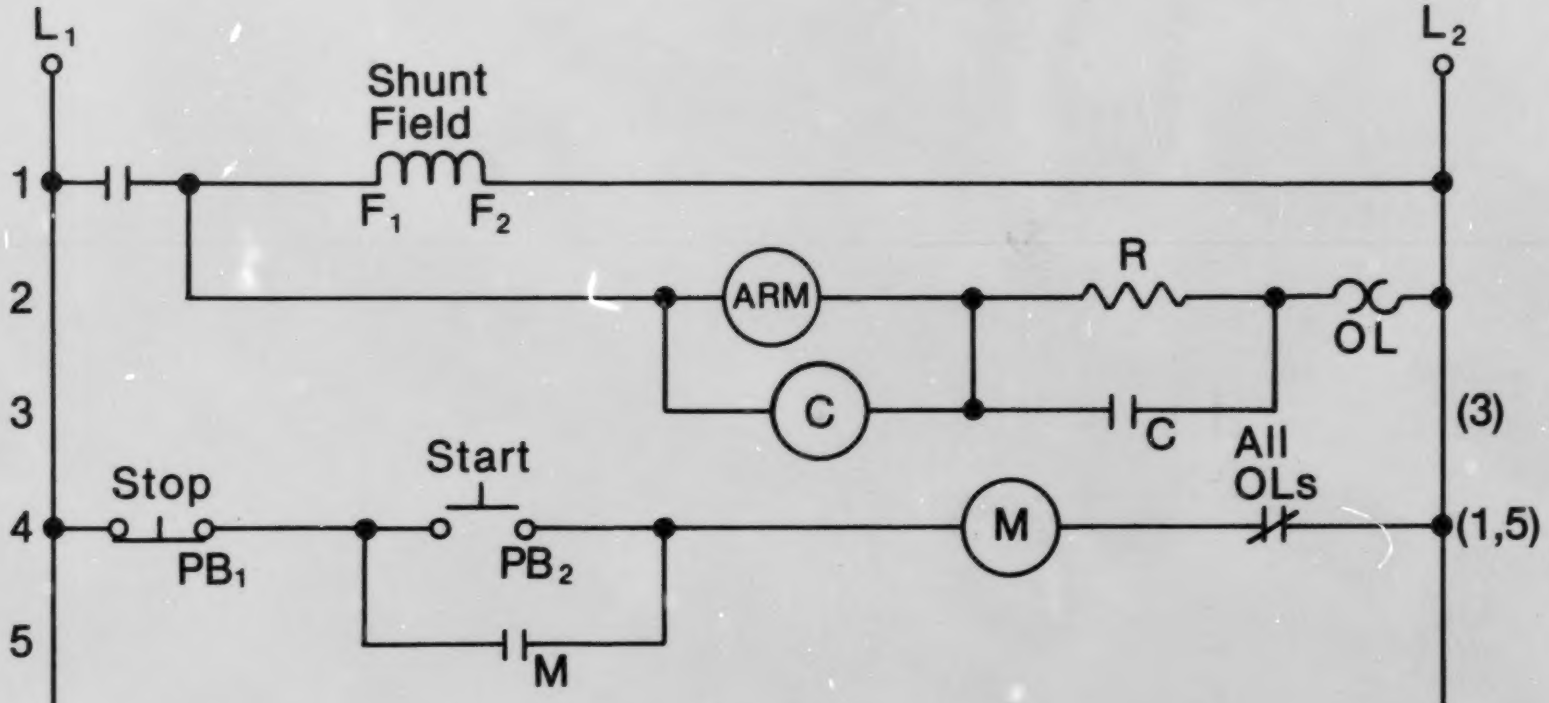
TM #7

IE - 101-A

101

102

Control Circuit of Counter Electromotive Force Acceleration Starter

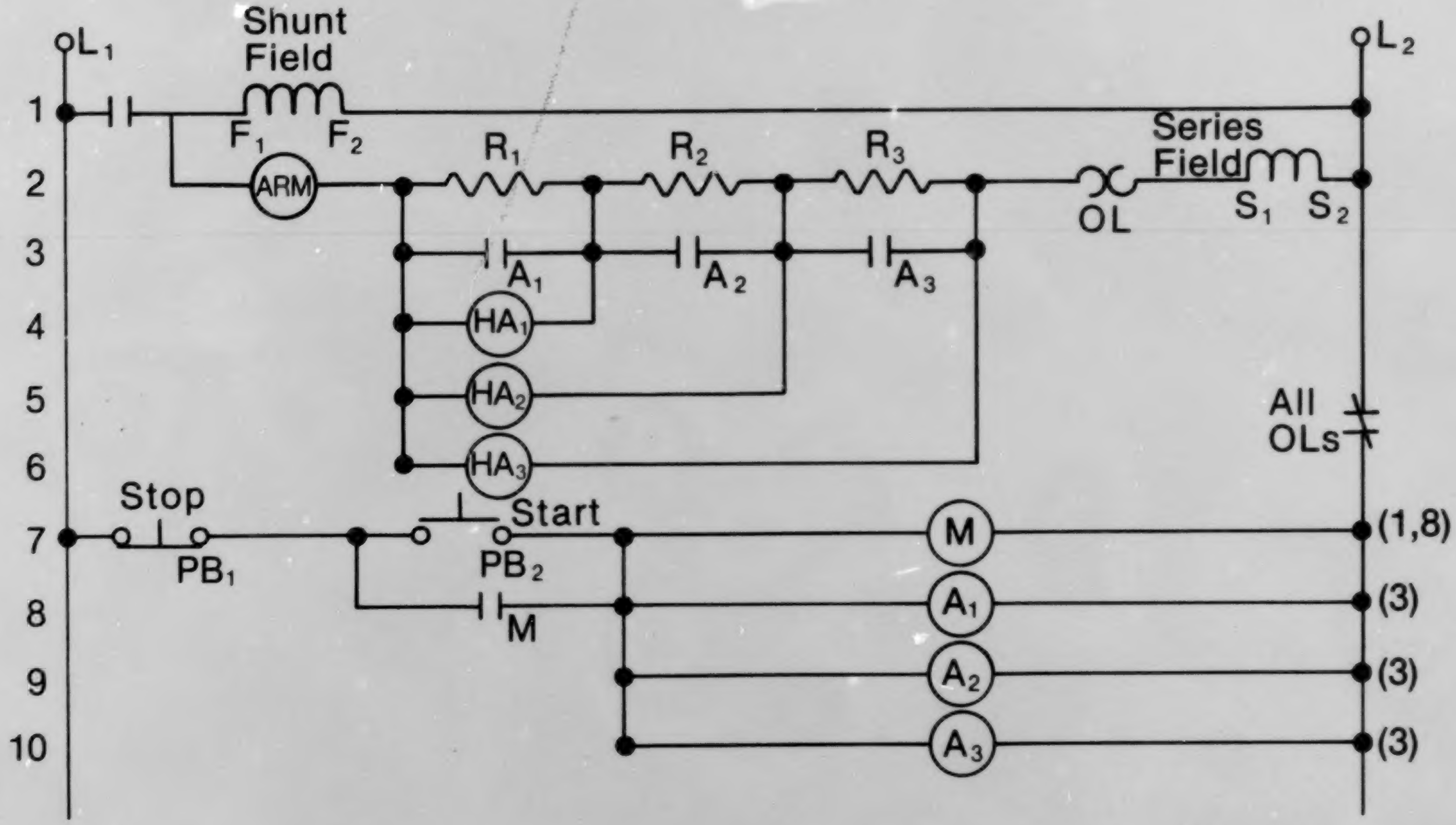

L₁
L₂
Shunt Field
F₁
F₂
1
2
3
4
5
ARM
R
OL
C
C
(3)
Stop
PB₁
Start
PB₂
M
All OLs
(1,5)
M

Voltage Drop Across Armature Activates Relay C

TM #8

IE - 103-A

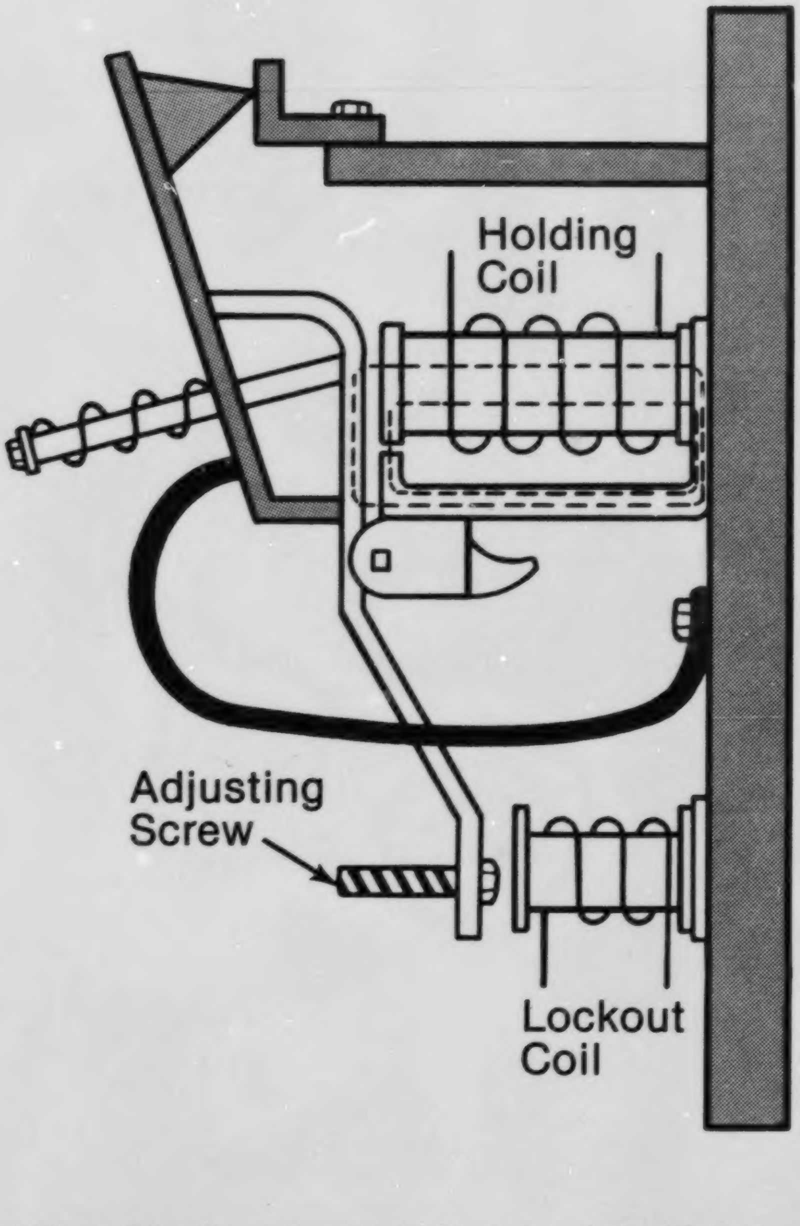
Control Circuit of Voltage-Drop Current-Limit Acceleration Starter


L₁
Shunt Field
L₂
1
F₁
F₂
2
ARM
R₁
R₂
R₃
OL
Series Field
S₁
S₂
3
A₁
A₂
A₃
4
HA₁
5
HA₂
6
HA₃
All OLs
Stop
Start
7
PB₁
PB₂
M
(1,8)
8
A₁
M
(3)
9
A₂
(3)
10
A₃
(3)

TM #9

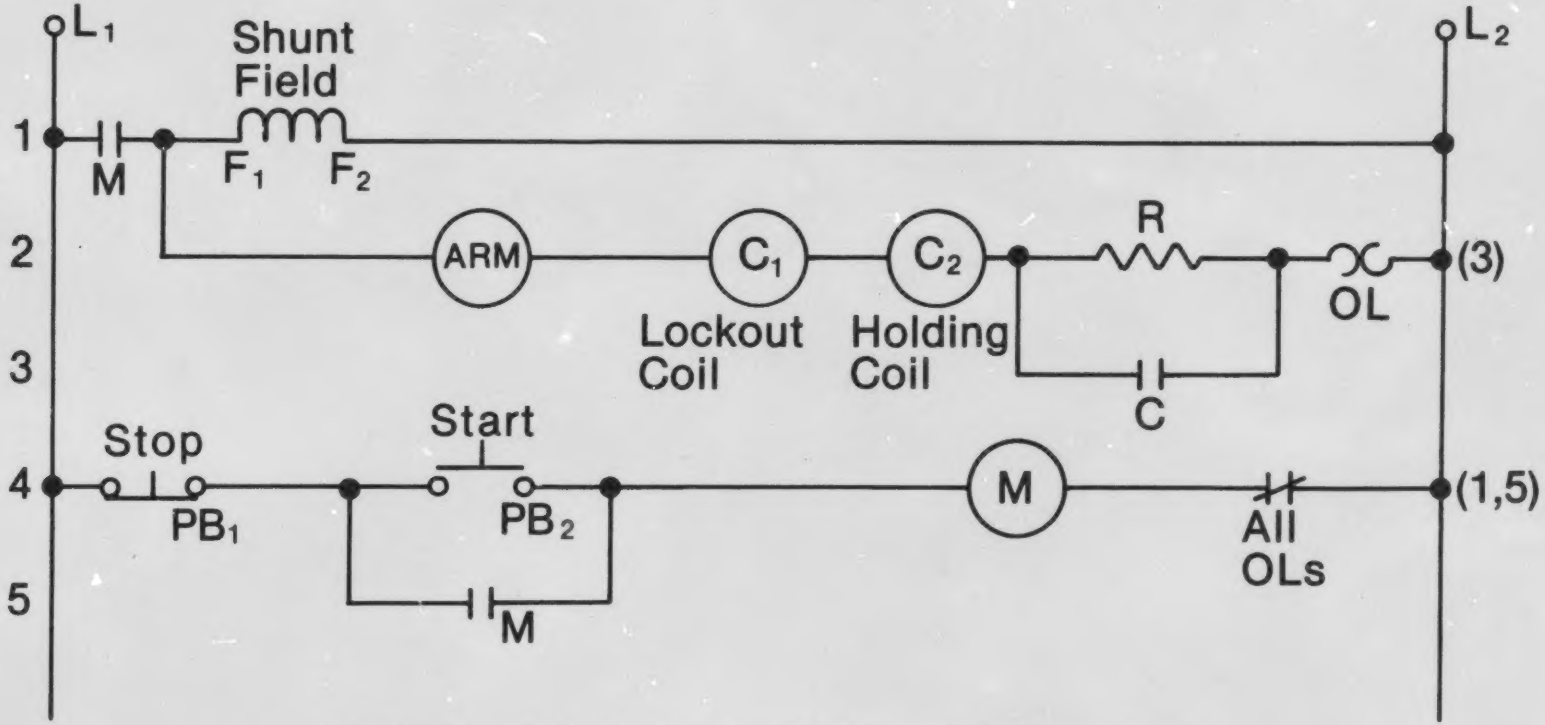
IE - 105-A

Double-Coil Lockout Relay


Holding Coil
Adjusting Screw
Lockout Coil

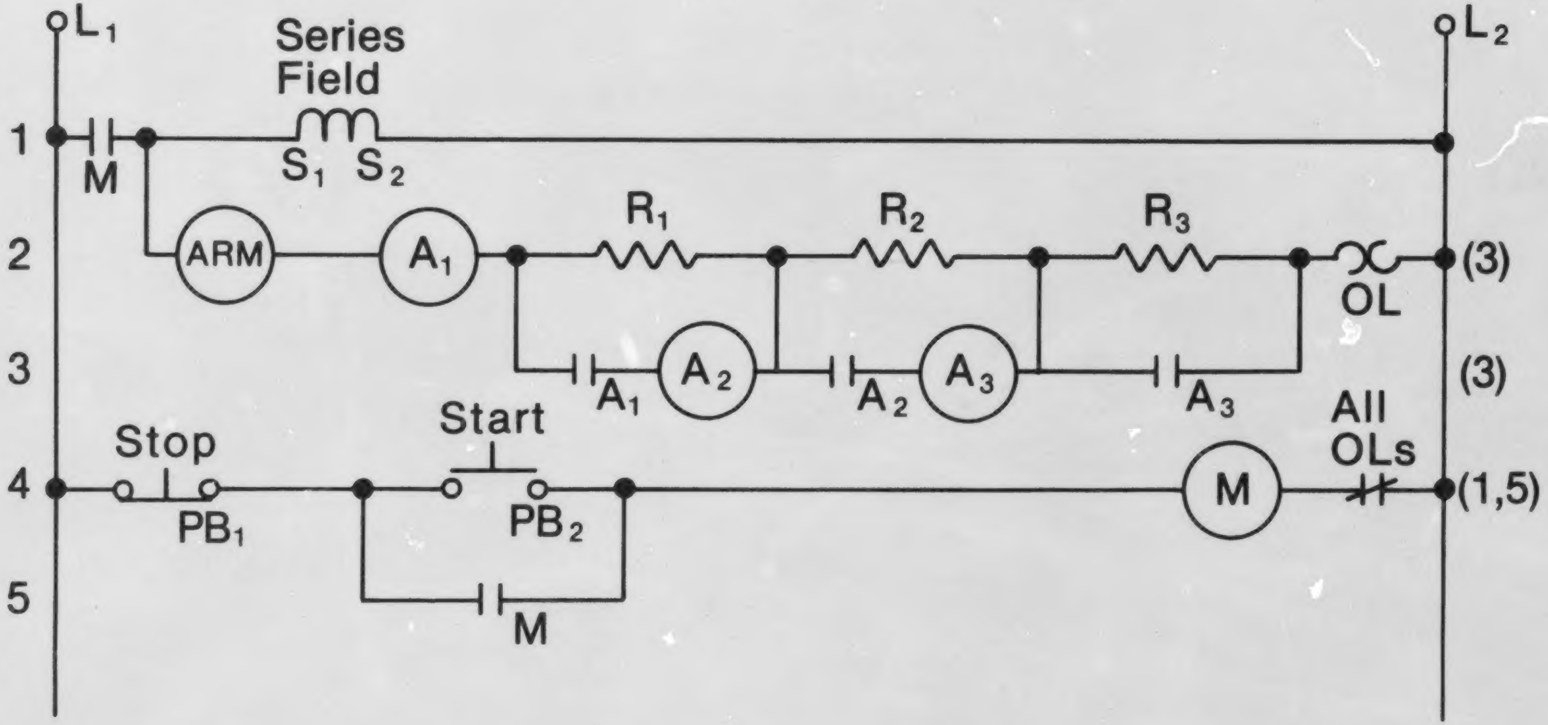
Source: *Electrical Power: Motors, Controls, Generators, Transformers* by Joe Kaiser, 1982, Goodheart-Wilcox Co., Inc.

Control Circuit of Lockout Acceleration Starter


L₁
L₂
1
2
3
4
5
M
Shunt Field
F₁
F₂
ARM
C₁
C₂
Lockout Coil
Holding Coil
R
OL
C
(3)
Stop
PB₁
Start
PB₂
M
All OLs
(1,5)
M

Coils C_1 and C_2 Are in Series with Armature

Control Circuit of Single-Coil Series Lockout Starter


L₁
L₂
Series Field
S₁
S₂
1
2
3
4
5
M
ARM
A₁
R₁
R₂
R₃
OL
(3)
A₂
A₃
A₁
A₂
A₃
(3)
Stop
Start
PB₁
PB₂
M
All OLs
(1,5)
M

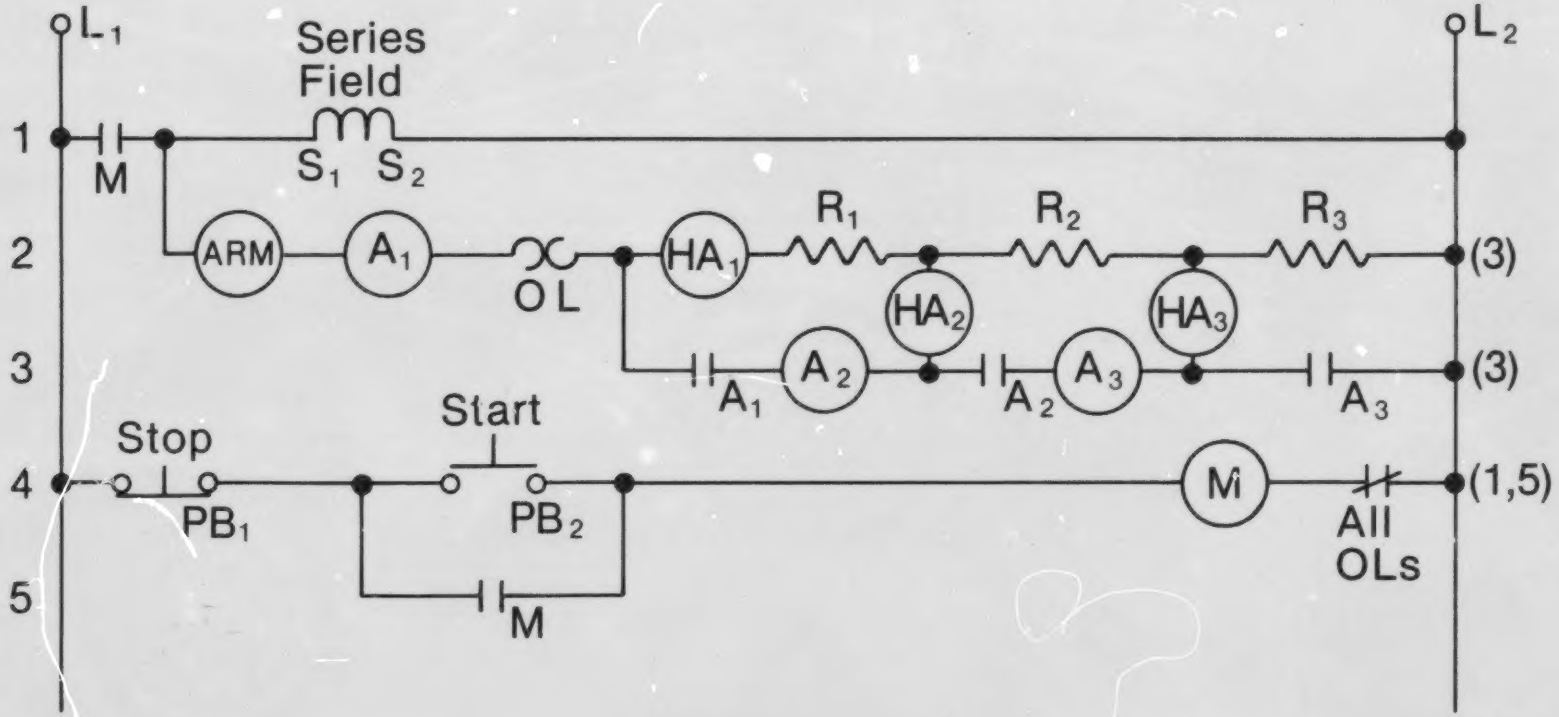
TM #12

110

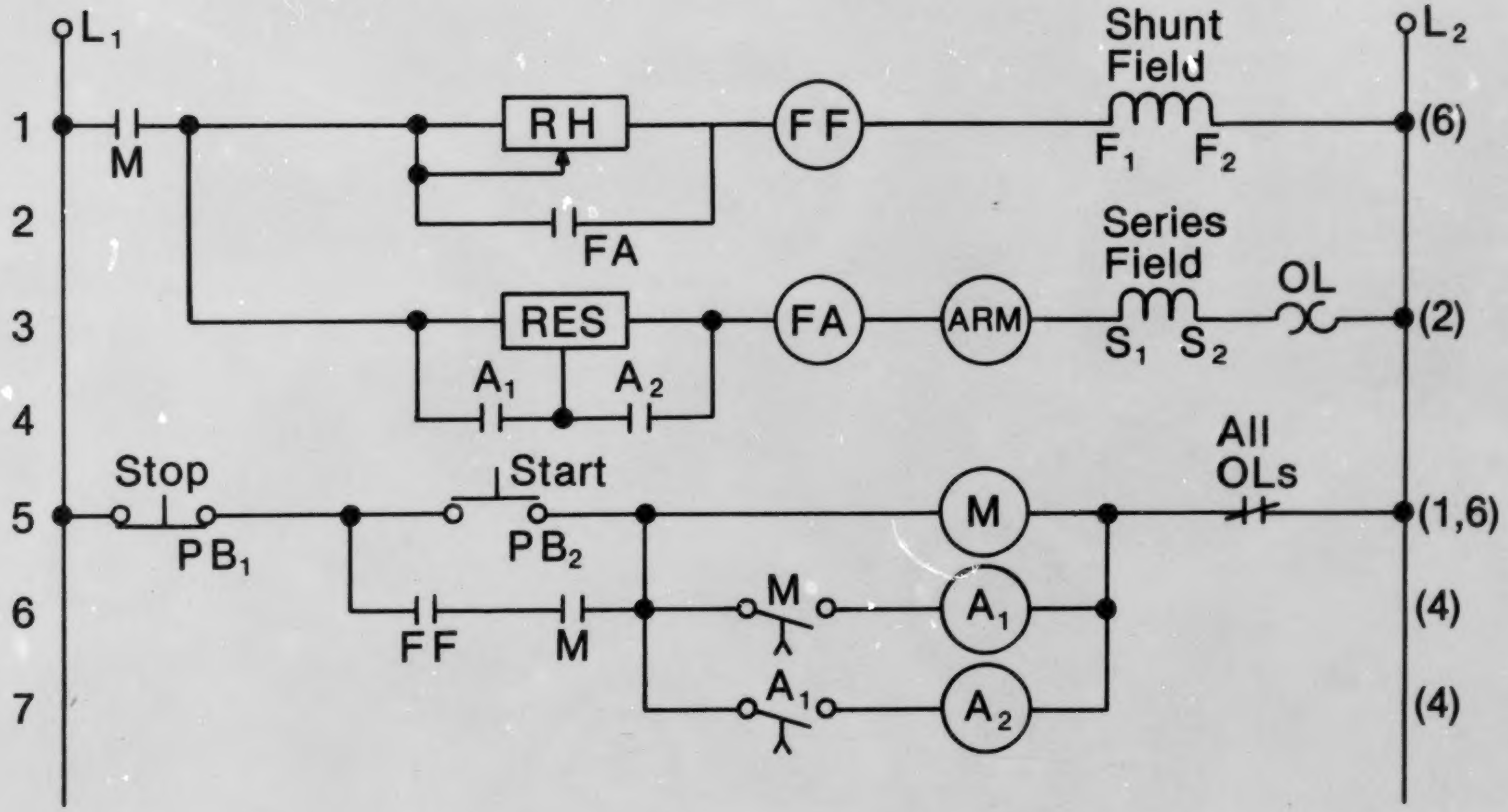
111

IE - 111-A

Control Circuit of Double-Coil Series Lockout Starter


L₁
L₂
Series Field
S₁
S₂
1
2
3
4
5
M
ARM
A₁
OL
HA₁
R₁
R₂
R₃
HA₂
HA₃
(3)
A₂
A₃
(3)
Stop
Start
PB₁
PB₂
M
All OLs
(1,5)
M

Control Circuit of Individual Dashpot Relay Acceleration Starter


L1
L2
1
2
3
4
5
6
7
M
RH
FF
FA
Shunt Field
F1
F2
(6)
RES
ARM
Series Field
S1
S2
OL
(2)
A1
A2
Stop
PB1
Start
PB2
M
All OLs
(1,6)
FF
M
A1
(4)
A2
(4)

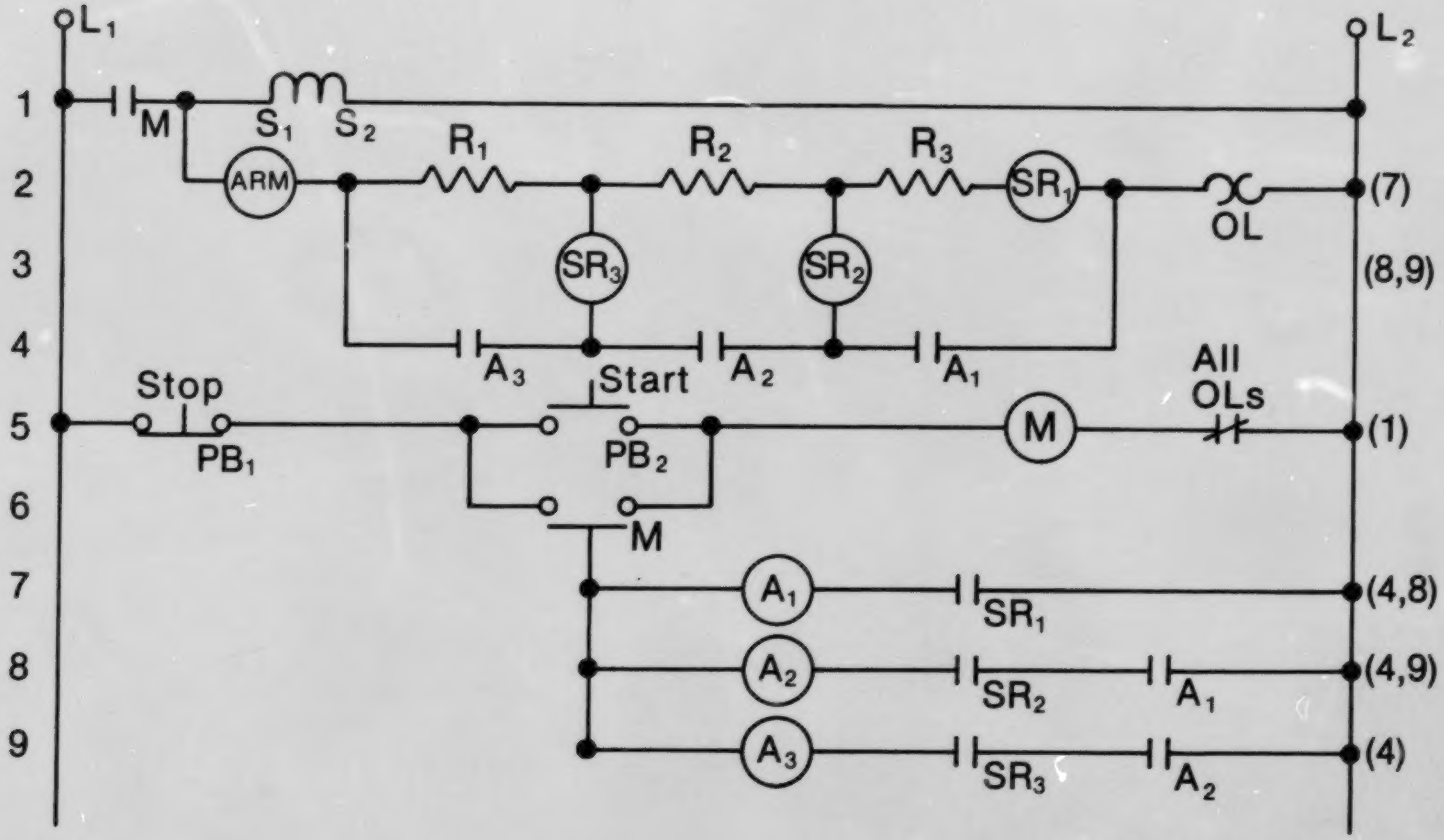
TM #14

114

115

IE - 115-A

Control Circuit of Series Relay Acceleration Starter


L1
L2
1
2
3
4
5
6
7
8
9
M
S_1
S_2
R_1
R_2
R_3
ARM
SR_1
OL
(7)
SR_3
SR_2
(8,9)
A_3
A_2
A_1
Stop
Start
All OLs
PB_1
PB_2
M
(1)
M
A_1
SR_1
(4,8)
A_2
SR_2
A_1
(4,9)
A_3
SR_3
A_2
(4)

TM #15

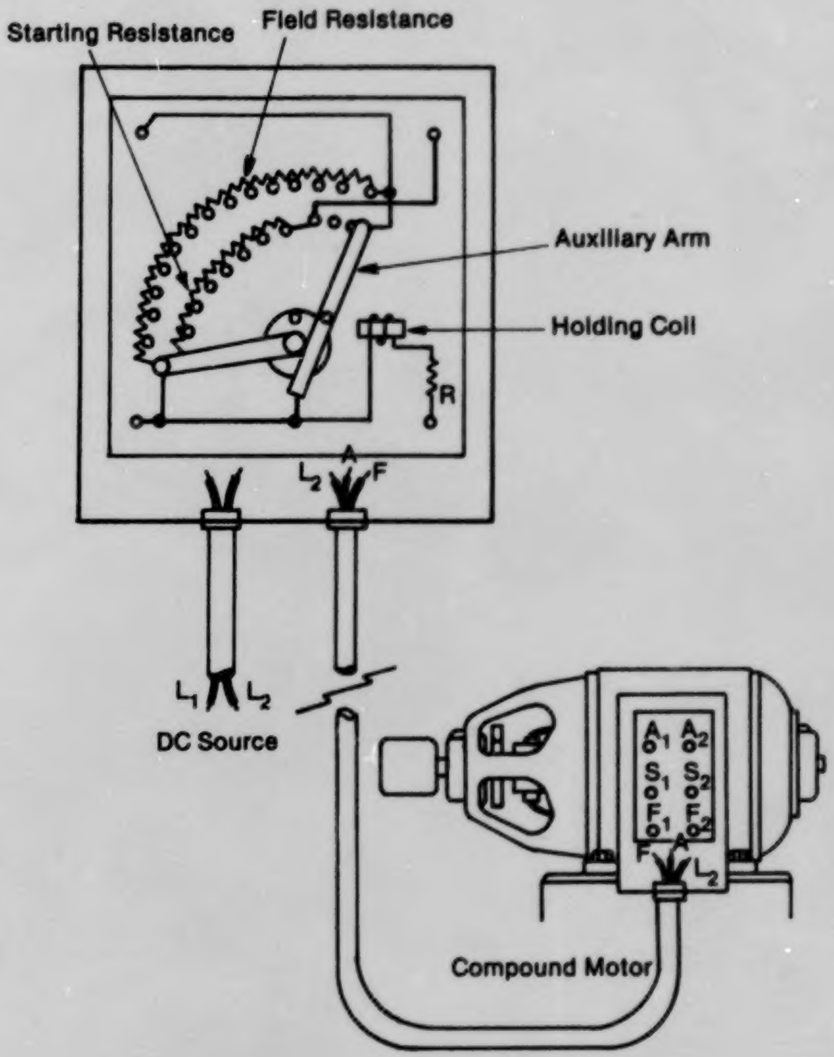
IE - 117-A

DC MOTOR CONTROLS
UNIT II

ASSIGNMENT SHEET #1 — DRAW INTERNAL AND EXTERNAL CONNECTIONS FOR A FOUR-POINT STARTER AND COMPOUND MOTOR

NAME ______________________ SCORE ____________

The technician will be asked to connect various direct current motors, the compound motor being one of many. Complete internal and external connections for the four-point starter and compound motor illustrated below.



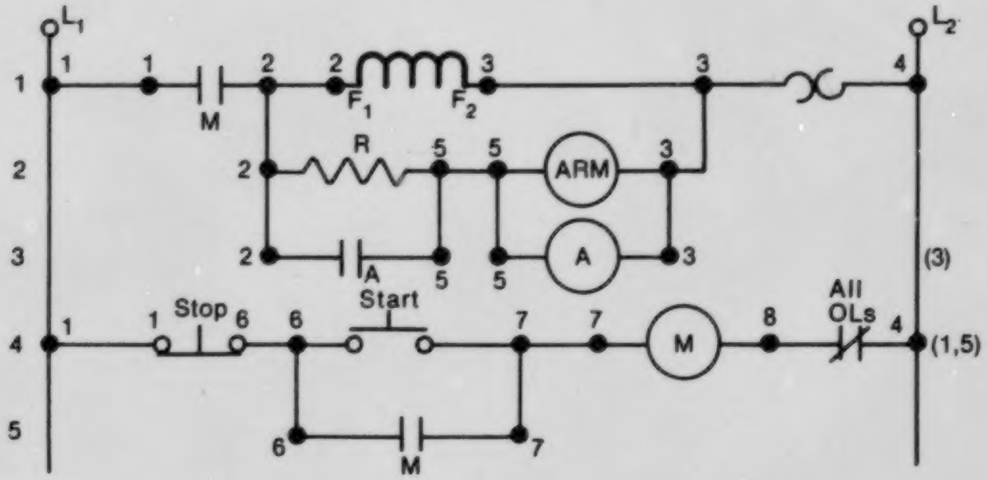
Starting Resistance
Field Resistance
Auxiliary Arm
Holding Coil
R
L_2
A
F
L_1
L_2
DC Source
A_1
A_2
S_1
S_2
F_1
F_2
F
A
L_2
Compound Motor

DC MOTOR CONTROLS
UNIT II

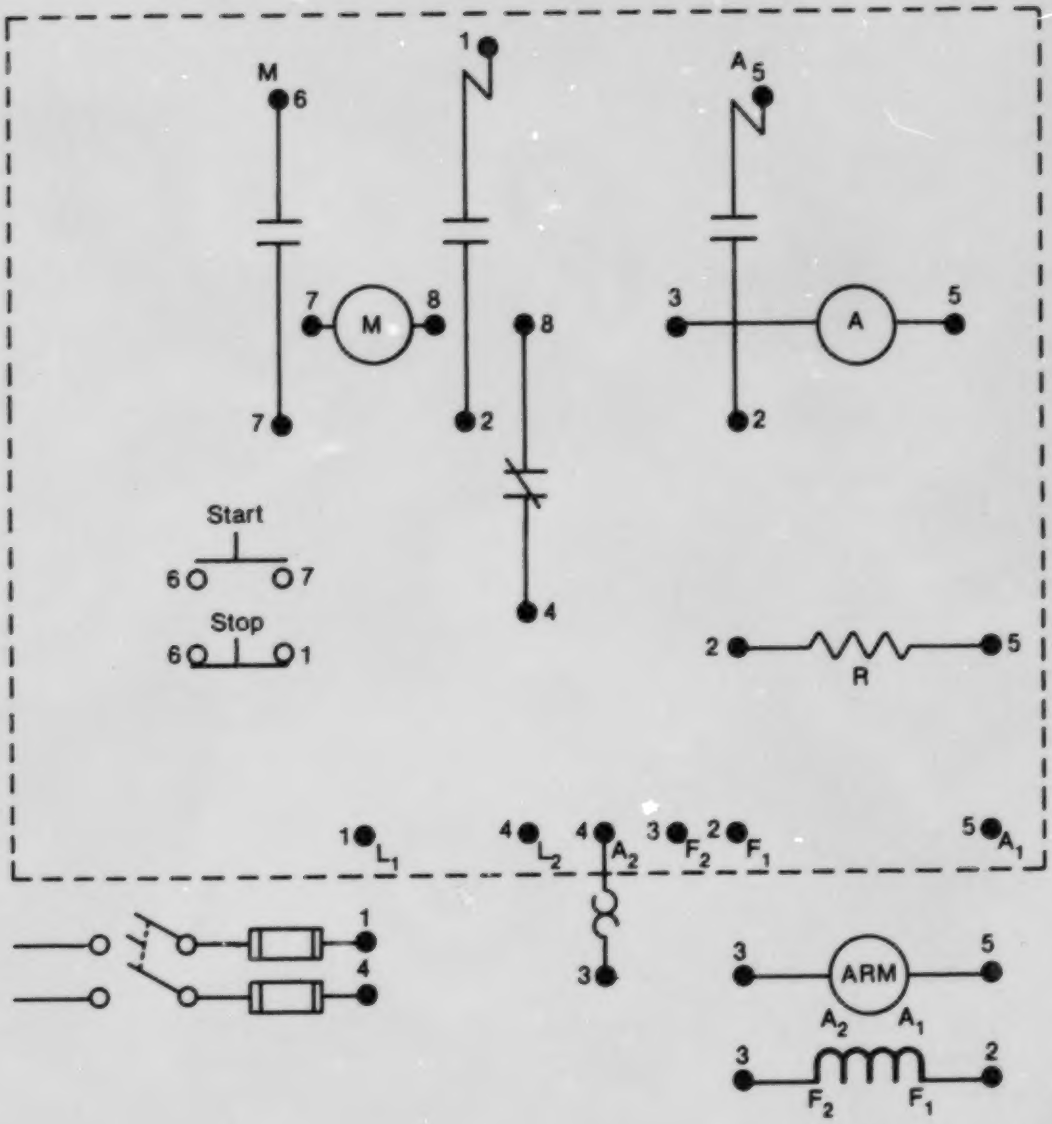
ASSIGNMENT SHEET #2 — COMPLETE A PANEL WIRING DIAGRAM OF A COUNTER ELECTROMOTIVE FORCE MOTOR CONTROLLER

NAME ______________________________ SCORE ____________

A technician must be familiar with and know how to interpret control circuit ladder diagrams and wiring diagrams. Refer to the numbered ladder diagram below to complete the connections on the panel wiring diagram on the following page.


L1
L2
1
2
3
4
5
M
F1
F2
R
ARM
A
Stop
Start
M
All OLs
(3)
(1,5)
1
2
3
4
5
6
7
8

ASSIGNMENT SHEET #2

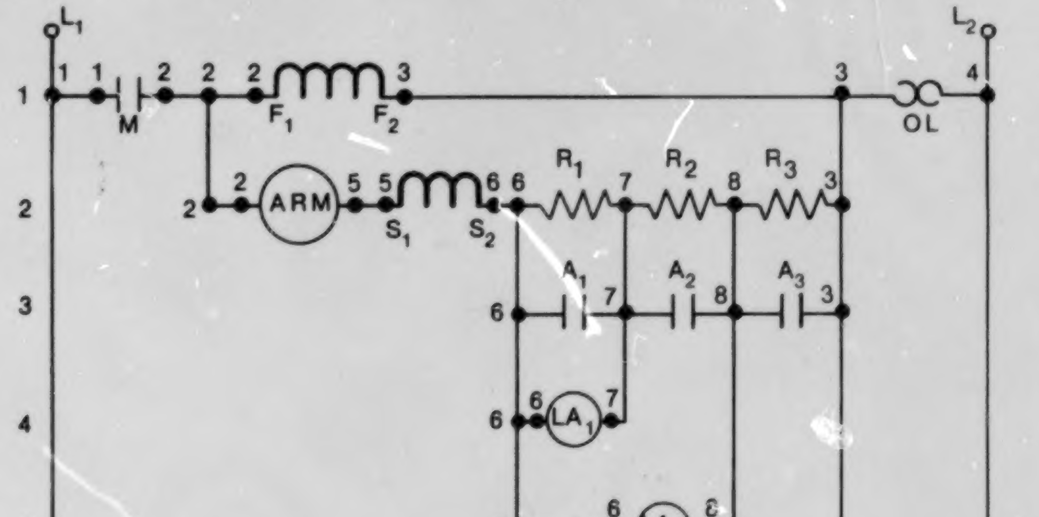

M
6
1
A
5
7
M
8
8
3
A
5
7
2
2
Start
6
7
4
Stop
6
1
2
R
5
1
L1
4
L2
4
A2
3
F2
2
F1
5
A1
1
4
3
3
ARM
5
A2
A1
3
2
F2
F1

DC MOTOR CONTROLS
UNIT II

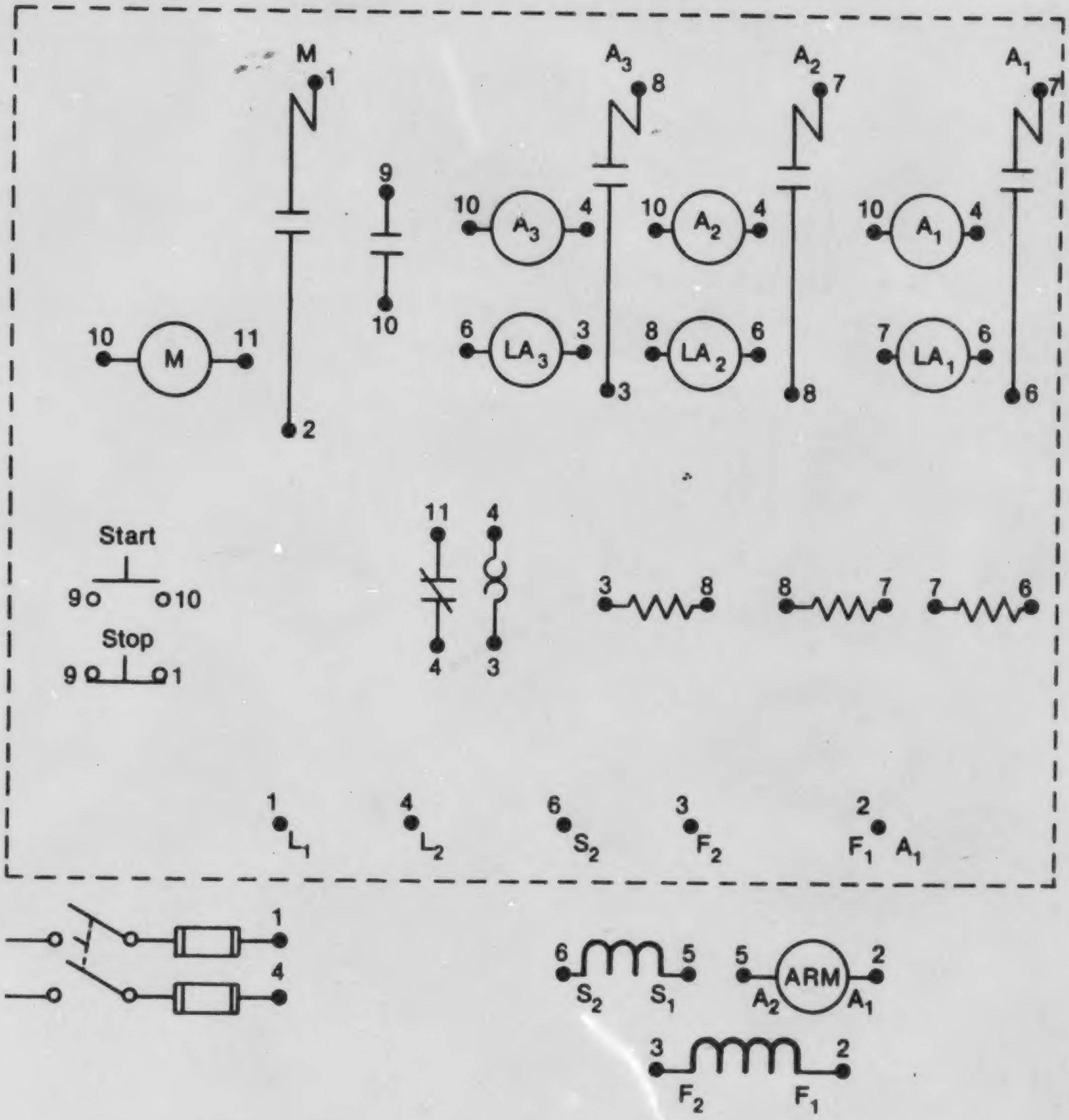
ASSIGNMENT SHEET #3 — COMPLETE A PANEL WIRING DIAGRAM OF A VOLTAGE-DROP CURRENT-LIMIT ACCELERATION CONTROLLER

NAME ______________________ SCORE __________

The panel wiring diagram of a voltage-drop current-limit acceleration controller is a wiring schematic with which the electrical technician must be familiar. Refer to the numbered ladder diagram below to complete the connections on the panel wiring diagram on the following page.


L1
L2
1
2
3
4
5
6
7
8
9
10
M
F1
F2
OL
ARM
S1
S2
R1
R2
R3
A1
A2
A3
LA1
LA2
LA3
Stop
Start
M
All OLs
A1
A2
A3
(1,8)
(3)
(3)
(3)

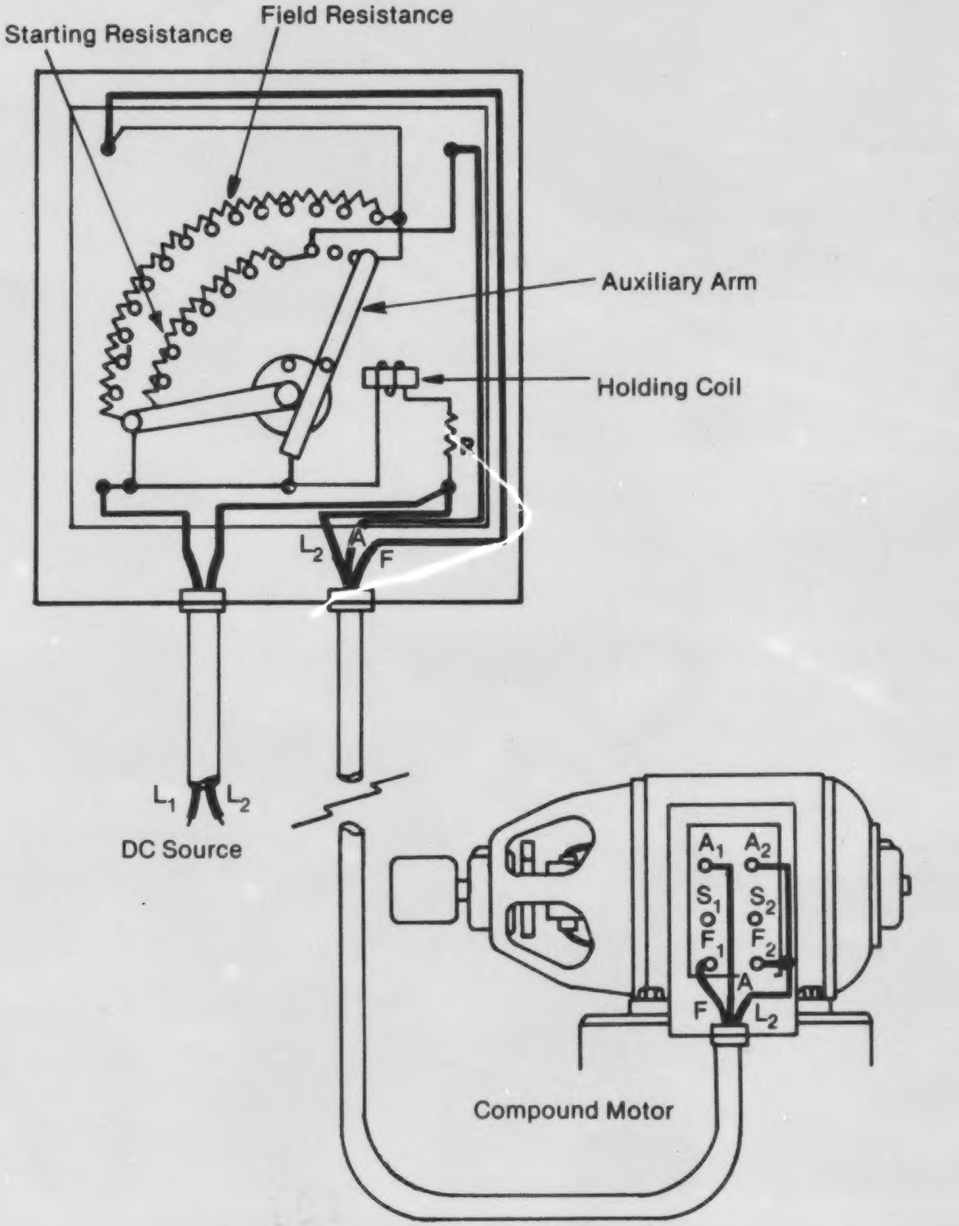
ASSIGNMENT SHEET #3


M
1
2
9
10
A3
8
3
A2
7
8
A1
7
6
10 A3 4
10 A2 4
10 A1 4
10 M 11
6 LA3 3
8 LA2 6
7 LA1 6
Start
9 10
Stop
9 1
11
4
4
3
3 8
8 7
7 6
1 L1
4 L2
6 S2
3 F2
2 F1 A1
1
4
6 S2
5 S1
5 A2
ARM
2 A1
3 F2
2 F1

DC MOTOR CONTROLS
UNIT II

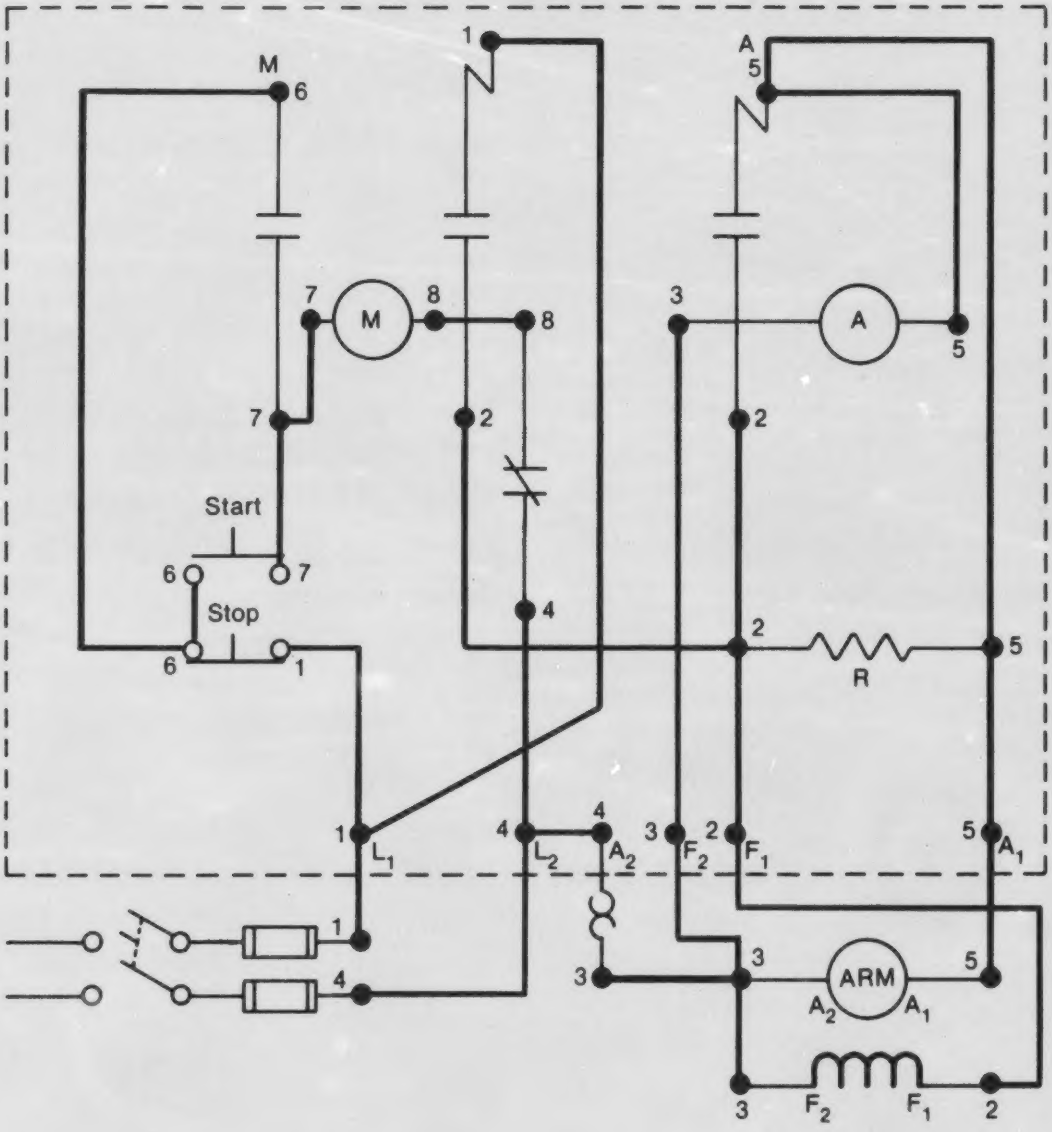
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1


Field Resistance
Starting Resistance
Auxiliary Arm
Holding Coil
L2
A
F
L1
L2
DC Source
A1
A2
S1
S2
F1
F2
A
F
L2
Compound Motor

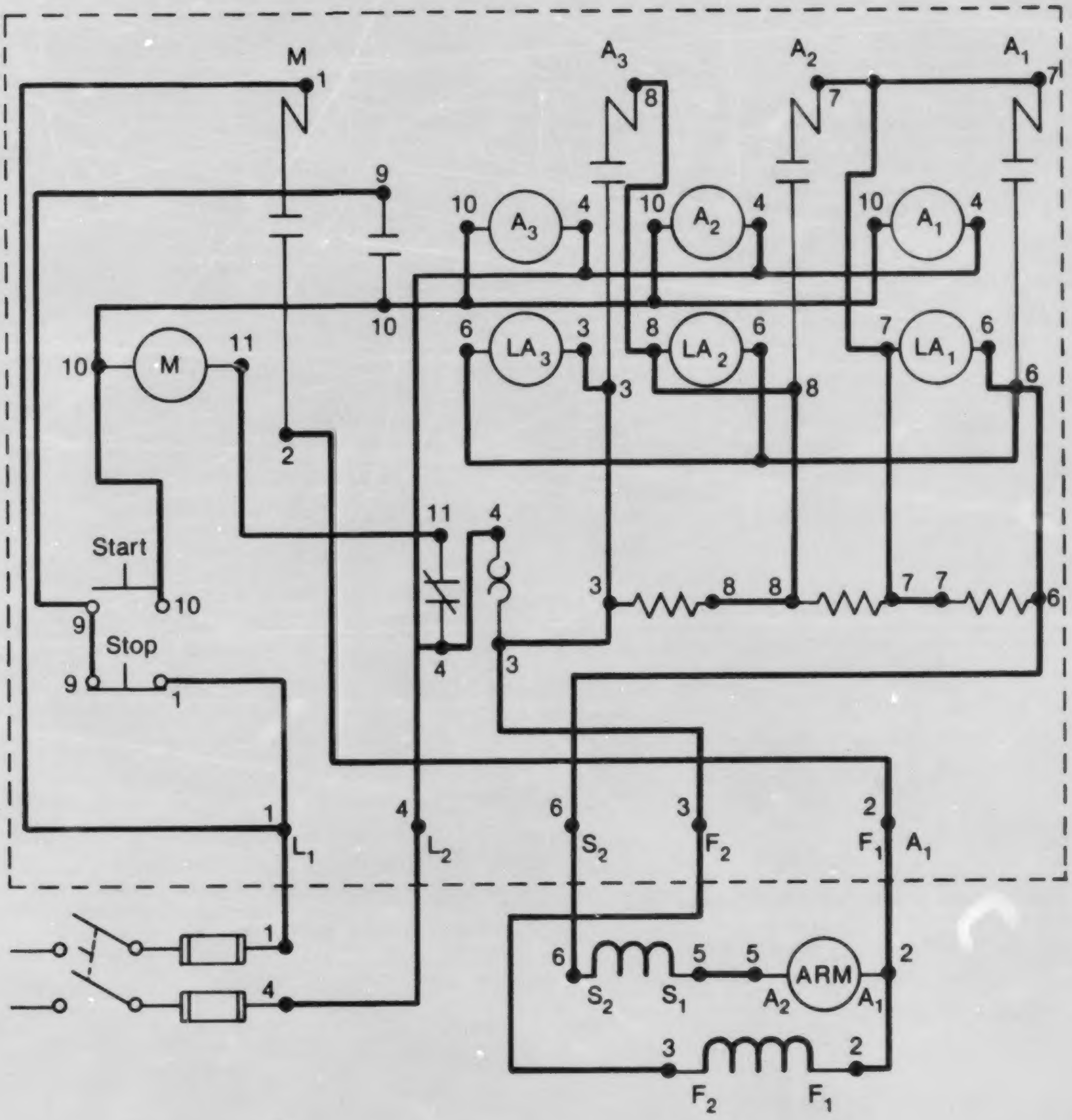
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2


M
6
1
A
5
7
M
8
8
3
A
5
7
2
2
Start
6
7
Stop
4
2
6
1
5
R
1
L1
4
L2
4
A2
3
F2
2
F1
5
A1
1
4
3
3
ARM
5
A2
A1
3
F2
F1
2

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3


M
A3
A2
A1
M
A3
A2
A1
LA3
LA2
LA1
Start
Stop
L1
L2
S2
F2
F1
A1
ARM
S1
A2

DC MOTOR CONTROLS
UNIT II

JOB SHEET #1 — CONNECT A MANUAL THREE-POINT STARTER BOX TO A DIRECT CURRENT MOTOR

I. Equipment and materials

- A. Combination wrench set
- B. Pliers
- C. Socket set
- D. Standard screwdriver
- E. Three-point starter
- F. Compound or shunt DC motor
- G. Multimeter
- H. Motor hookup wire, #14
- I. Terminal marking labels
- J. DC power supply of 120/240 volts
- K. Eye protection

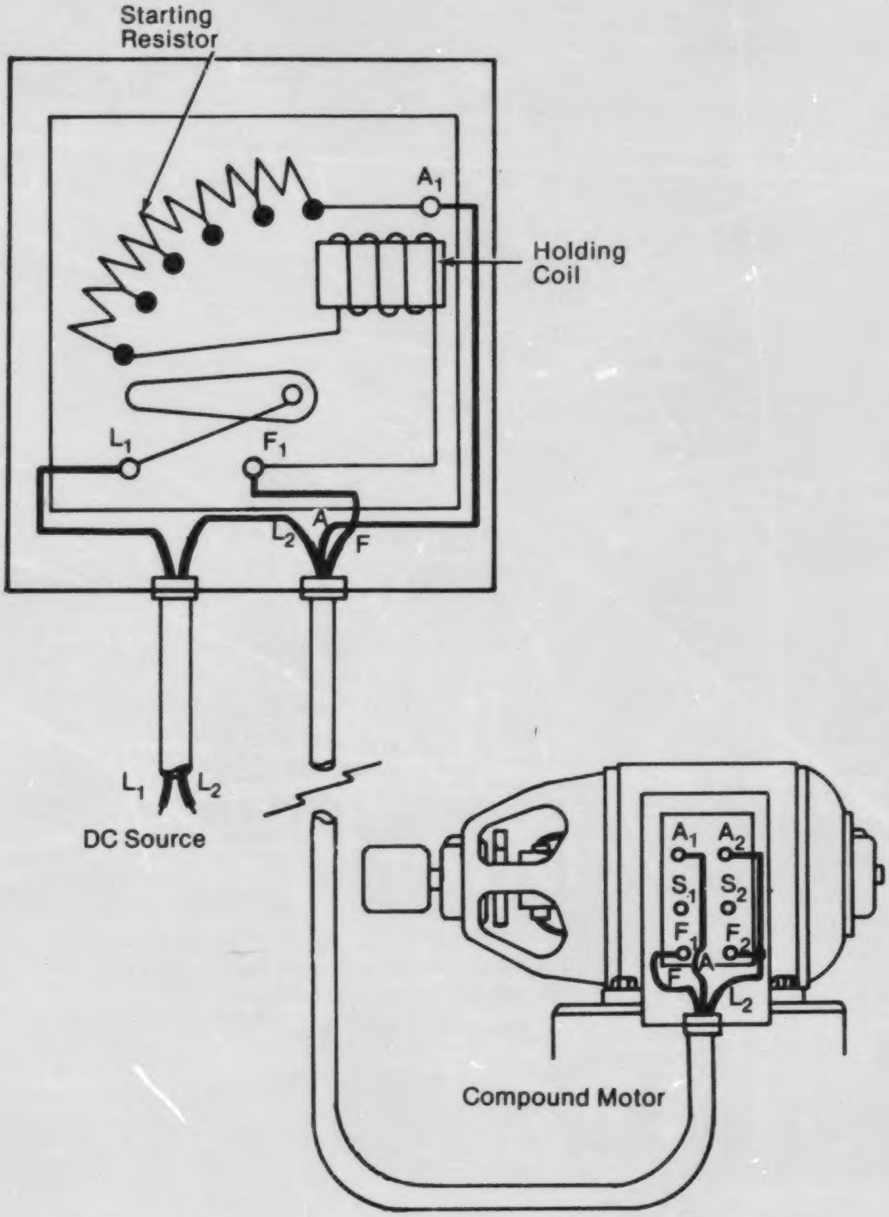
II. Procedure

- A. Observe safety precautions when working on electrical equipment
    1. Make sure that equipment is de-energized before working on it
    2. Use proper apparatus to test whether equipment is safe to work on
    3. Use proper equipment to de-energize controller
    4. Put on eye protection
- B. Check material with motor and controller in place
- C. Measure #14 motor hookup wire

JOB SHEET #1

D. Make connections to motor A1, A2, and F2 (Figure 24)

FIGURE 24


Starting Resistor
A_1
Holding Coil
L_1
F_1
A
L_2
F
L_1
L_2
DC Source
A_1
A_2
S_1
S_2
F_1
F_2
F
A
L_2
Compound Motor

JOB SHEET #1

E. Make connections to starter terminals, A1, F1, and L1 (See Figure 24)

(NOTE: To avoid making connection errors, attach a terminal marker to each lead. Have instructor check connections.)

F. Turn on power to starter

G. Put starter in position one (first notch) and check for motor rotation

H. Reverse rotation if it is wrong according to motor nameplate

I. After checking for rotation, turn control arm gradually toward full speed

(NOTE: After the motor reaches full speed, the holding coil should hold the arm on until turned off or until loss of power.)

J. Turn off motor when test is completed

K. Turn off power to starter

L. Disconnect all leads

M. Clean work area and store equipment properly

DC MOTOR CONTROLS
UNIT II

JOB SHEET #2 — CONNECT A THREE-POINT STARTER BOX AND REVERSING SWITCH IN THE ARMATURE CIRCUIT OF A SHUNT MOTOR

I. Equipment and materials

- A. Three-point starter box
- B. DC shunt motor
- C. Reversing switch
- D. Combination wrench set
- E. Socket set
- F. Standard screwdriver
- G. Hookup wire, #14
- H. DC power supply of 120/240 volts
- I. Eye protection

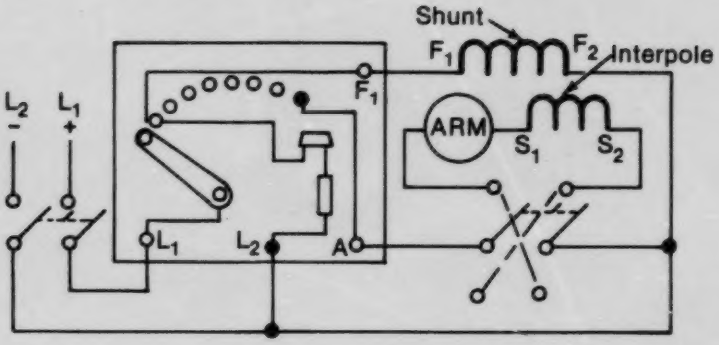
II. Procedure

- A. Observe safety precautions when working on electrical equipment
    1. Make sure that equipment is de-energized before working on it
    2. Use proper apparatus to test whether equipment is safe to work on
    3. Use proper equipment to de-energize controller
    4. Put on eye protection
- B. Check material with motor and starter box in place
- C. Check to see that power to controllers is off

    (NOTE: If six leads are brought out of the motor, care must be taken to connect the motor for cumulative operation.)

D. Make connections to motor (Figure 25)

FIGURE 25



E. Make connections to reversing switch

F. Make connections to starter box

(NOTE: Allow motor to come to a full stop before attempting to operate it in the opposite direction. Have instructor check connections.)

G. Throw reversing switch

H. Slowly raise handle of starter

(NOTE: If sparking occurs, motor has interpoles that were not reversed. Motor connections are L1 to L1 to reversing switch F1 to F1.)

I. When it reaches speed, stop motor and reverse it

(NOTE: Let motor come to complete stop before reversing it.)

J. Check rotation

K. Move handle to OFF position to stop

L. Turn off power to starter

M. Disconnect all leads to starter and motor

N. Clean work area and store equipment properly

DC MOTOR CONTROLS
UNIT II

JOB SHEET #3 — CONNECT A FOUR-POINT STARTER BOX TO A SHUNT MOTOR

I. Equipment and materials

- A. Four-point starter box
- B. Shunt motor
- C. DC power supply of 120/240 volts
- D. Tachometer
- E. Field rheostat
- F. Combination wrench set
- G. Standard screwdrivers
- H. Socket set
- I. Terminal-marking labels
- J. Eye protection

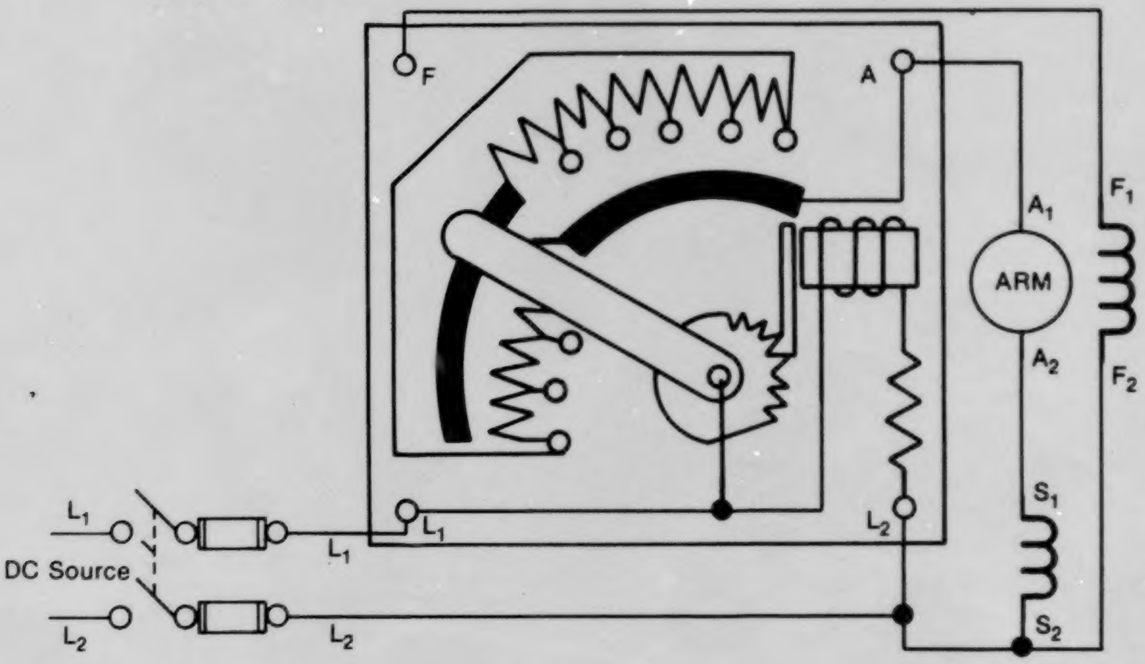
II. Procedure

- A. Observe safety precautions when working on electrical equipment
  1. Make sure that equipment is de-energized before working on it
  2. Use proper apparatus to test whether equipment is safe to work on
  3. Use proper equipment to de-energize controller
  4. Put on eye protection
- B. Check to see that power supply switch is off (check switch blades)

JOB SHEET #3

C. Connect four-point starter box to shunt motor (Figure 26)

FIGURE 26



D. Turn field rheostat to OUT or OFF position

E. Close line switch and start motor by gradually advancing handle to running position

F. Note direction of rotation, and record speed as determined by the tachometer

Speed = ______________________ rpm

G. Gradually increase resistance with tachometer in place; note any change in speed

(CAUTION: Do not allow motor to run at more than 150 percent of rated speed.)

H. Turn field rheostat to OUT position and open main switch; note action of holding coil

I. Reverse direction of motor

JOB SHEET #3

J. Repeat steps D through H

Speed = ____________________ rpm

K. Turn field rheostat to out or OFF position and shut down motor

L. Disconnect all leads to motor and starter box

M. Clean work area and store equipment properly

DC MOTOR CONTROLS
UNIT II

JOB SHEET #4 — CONNECT A COUNTER ELECTROMOTIVE FORCE CONTROLLER TO A DIRECT CURRENT COMPOUND MOTOR

I. Equipment and materials

- A. DC compound motor
- B. Counter electromotive force controller
- C. Safety switch
- D. Start/stop push button
- E. Combination wrench set
- F. Socket set
- G. Standard screwdrivers
- H. DC power supply of 120/240 volts
- I. Motor hookup wire, #14
- J. Eye protection

II. Procedure

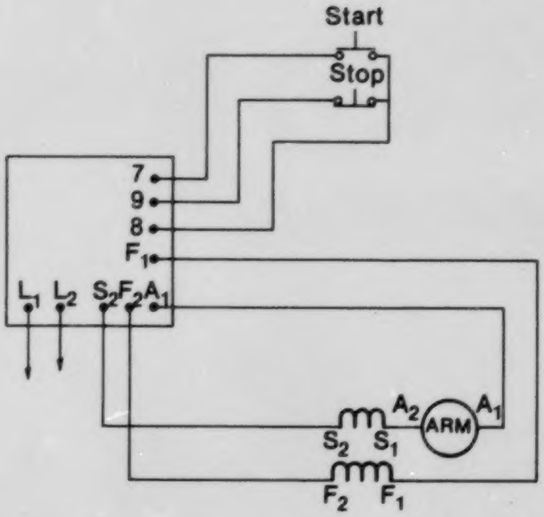
- A. Observe safety precautions when working on electrical equipment
  1. Make sure that equipment is de-energized before working on it
  2. Use proper apparatus to test whether equipment is safe to work on
  3. Use proper equipment to de-energize controller
  4. Put on eye protection
- B. Make sure that power is off at safety switch

JOB SHEET #4

C. Connect motor and power to controller as shown in Figure 27

(NOTE: Have instructor check connections.)

FIGURE 27



D. Turn on safety switch to controller

E. Push start button

F. Note direction of rotation of motor

G. Push stop button

H. Open safety switch; check open and lock open

I. Disconnect controller and motor connections

J. Store material properly

K. On the following page, draw a schematic diagram of this installation

JOB SHEET #4

DC MOTOR CONTROLS
UNIT II

JOB SHEET #5 — CONNECT A DRUM CONTROLLER TO A DIRECT CURRENT COMPOUND MOTOR

I. Equipment and materials

A. DC drum controller

B. Grid resistors

C. DC compound motor

D. Fused safety switch

E. Tachometer

F. Conduit

G. Conduit connecting material

H. Combination wrench set

I. Standard screwdrivers

J. Needlenose pliers

K. Lineman's pliers

L. Hookup wire, #14

M. Terminal-marking labels

N. Eye protection

II. Procedure

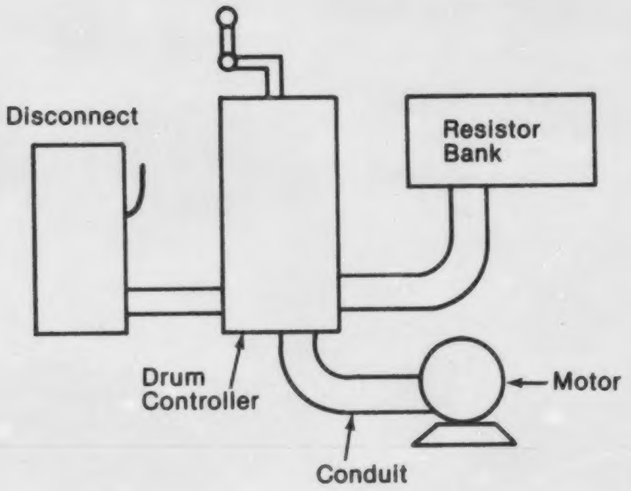
A. Observe safety precautions when working on electrical equipment

1. Make sure that equipment is de-energized before working on it
2. Use proper apparatus to test whether equipment is safe to work on
3. Use proper equipment to de-energize controller
4. Put on eye protection

JOB SHEET #5

B. Connect equipment (Figure 28)

FIGURE 28

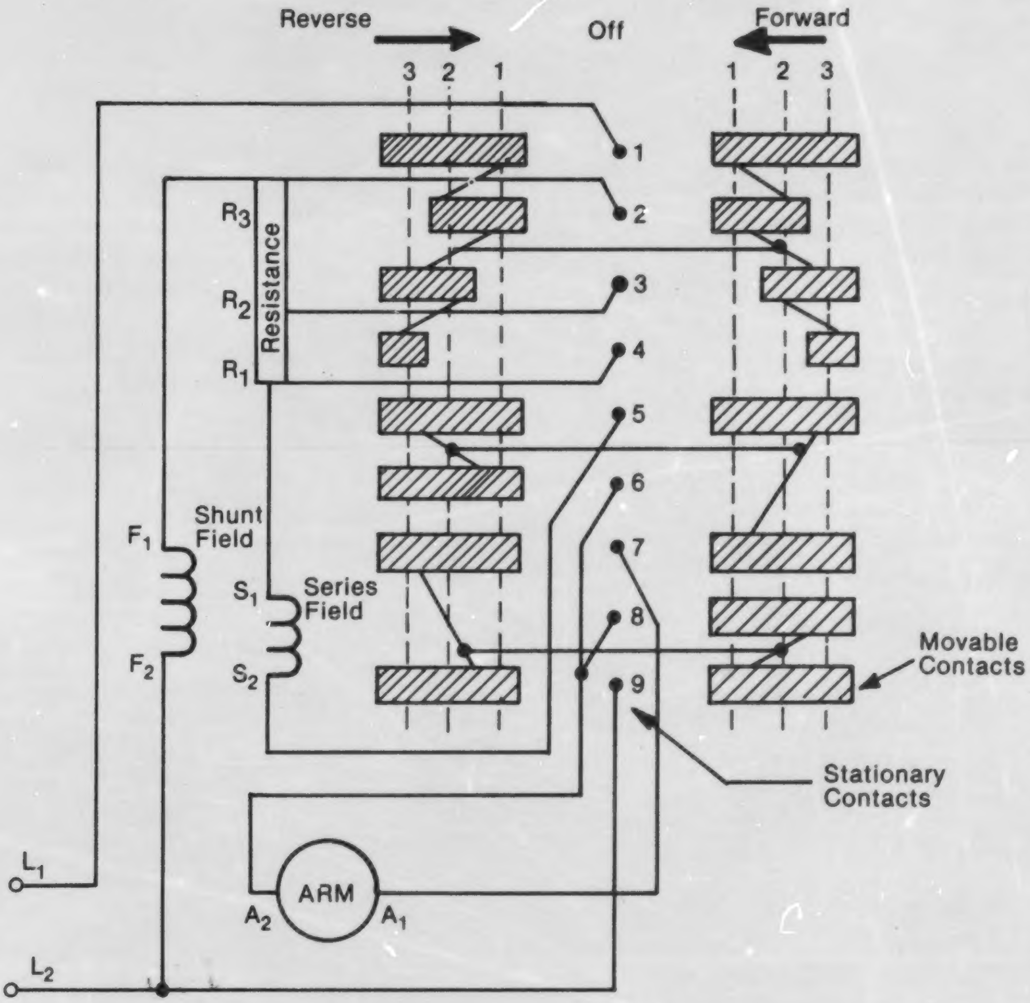

Disconnect
Resistor Bank
Drum Controller
Motor
Conduit

JOB SHEET #5

C. Follow the wiring diagram below in making necessary connections (Figure 29)

(NOTE: Different manufacturers may show different connections. Check controller cover for correct connections. Have instructor check circuit.)

FIGURE 29


Reverse
Off
Forward
3
2
1
1
2
3
1
2
3
4
5
6
7
8
9
R3
R2
R1
Resistance
Shunt Field
F1
F2
S1
S2
Series Field
Movable Contacts
Stationary Contacts
L1
L2
ARM
A2
A1

JOB SHEET #5

D. Turn on safety switch

E. Start motor by moving handle to first forward position; note direction of rotation and record speed

Speed = ____________________ rpm

F. Return drum switch to OFF position

G. Repeat step E with controller handle turned in the reverse direction

Speed = ____________________ rpm

H. Stop motor

I. Open safety switch (check and lock open)

J. Disconnect all leads to motor, controller, and safety switch

K. Disassemble material; clean work area and store equipment properly

DC MOTOR CONTROLS
UNIT II

JOB SHEET #6 — USE A MULTIMETER AND SCHEMATIC DIAGRAM TO TROUBLESHOOT A DIRECT CURRENT CONTROLLER

I. Equipment and materials

   A. Multimeter

   B. Screwdrivers

   C. Combination wrench set

   D. Needlenose pliers

   E. Fuse pullers

   F. DC controller

   G. DC motor

   H. Controller hookup wire, #14

   I. Eye protection

   J. Schematic diagram for DC controller

   K. Appropriate instruction manual

II. Procedure

   A. Observe safety precautions when working on electrical equipment

      1. Make sure that equipment is de-energized before working on it

      2. Use proper apparatus to test whether equipment is safe to work on

      3. Use proper equipment to de-energize controller

      4. Put on eye protection

   B. Narrow trouble to a specific circuit by observing how the controller operates when start button is depressed

   EXAMPLES: Pilot circuit — Includes all components needed to energize M coil

   Armature circuit — Anything that carries armature current; includes all M and A main contacts, overload heat-sensing element, starting resistance, and armature

   Accelerating circuit — Includes the A coils that are not part of pilot circuit, and contacts or devices that are associated with the A coil

JOB SHEET #6

(NOTE: All main contacts are considered part of the armature circuit. Use manufacturer's instruction book as applicable.)

Holding circuit — Used in conjunction with a momentary master switch to bypass the start button; always has at least one normally open M contact

C. If nothing happens when start button is pushed

1. Check fuses and power on L1 and L2

2. Use multimeter

   (NOTE: Make sure you are on the right scale and setting.)

3. If power is available in L1 and L2 and the fuses are good, check pilot circuit

   (CAUTION: Make sure the circuit is de-energized before you start troubleshooting.)

4. Use schematic diagram to read continuity between connection points

D. Push start button; suppose the M contacts close, but the motor does not run

(NOTE: Check armature circuit.)

E. Push start button; suppose the controller operates and the motor runs, but the A contactor does not operate

(NOTE: Check the accelerating circuit.)

F. Push start button; suppose the controller and the motor operate but stop when start button is released

(NOTE: Check holding circuit.)

G. After determining the circuit that the trouble is in, deenergize the controller

1. Use ohmmeter to read the faulty circuit

2. Start at one end of circuit; do not remove one test probe except to bypass high resistance devices such as a shunt coil or a normally open contact; use R x 1 scale of ohmmeter as much as possible

   (NOTE: Shunt coil may have a resistance as high as 2,000 ohms.)

H. Clean work area and store equipment properly

DC MOTOR CONTROLS
UNIT II

TEST

NAME ____ SCORE ________________

1. Match to their correct definitions terms associated with direct current motor controls. Write the correct numbers in the blanks. Terms and definitions are continued on the following page.

_____a. Limiting motor acceleration by changes in current brought on by current-sensitive relays

_____b. Electromagnetic coil used in contactors and starters to extinguish or deflect an arc when a circuit is interrupted

_____c. Motor control contacts that are open only while the push button is depressed

_____d. Motor control contacts that are closed only while the push button is depressed

_____e. Device for starting a motor in either direction of rotation, or adjusting speed of rotation or torque

_____f. Magnetic control in which service is disconnected automatically as a result of power failure; motor must be manually restarted when power is restored

_____g. Controller with electrical connecting parts in the form of fingers held by springs against contacts or surfaces on the perimeter of a rotating cylinder

_____h. Magnetic control that automatically disconnects service as a result of power failure; motor automatically restarts when power is restored

_____i. Device that delays closing or opening of a circuit for a specific period of time

1. Current-limit acceleration
2. Drum switch
3. Controller
4. Blowout coil
5. Timer
6. Low-voltage protection (LVP)
7. Normally open contacts
8. Low-voltage release (LVR)
9. Normally closed contacts

TEST

_____j. Piston moving inside a cylinder filled with air, oil, mercury, or other fluid

_____k. Motor starter having a manually controlled wiper arm and several taps, which are contacted by the wiper arm

_____l. Starting and bringing a motor up to operating speed in a definite time span regardless of its load

_____m. Direct current motor with two types of field coils: a shunt field coil connected in parallel with the armature, and a series field coil wired in series with the armature

_____n. Relay that weakens field strength in a motor to increase speed after it has started with full-strength field

_____o. Device or switch that starts an electric motor by connecting it directly to the supply line

_____p. Motor control mechanism that uses automatic pilot devices such as pressure switches, level switches, or thermostats as activating devices

_____q. Relay that slows down motor as it is pulled into operation by armature current and creates resistance in the motor circuit

_____r. Mechanical device used to control start windings in electric motors; may be set to prevent the operation of a push button

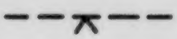
_____s. Semiconductor device that blocks voltage applied in either direction; used to control value of armature voltage, and provide a very accurate speed control of DC shunt motors

_____t. Small contacts that operate at the same time as the main contacts; govern succeeding operations of the same or allied devices, and may be either electrical or mechanical

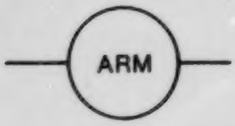
10. Field accelerating relay
11. Across-the-line starter
12. Faceplate controller
13. Silicon-controlled rectifier (SCR)
14. Dashpot
15. Interlocks
16. Automatic controller
17. Time-limit acceleration
18. Field decelerating relay
19. Compound motor
20. Lockout

TEST

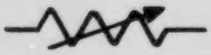
2. Label the following direct current motor schematic symbols.



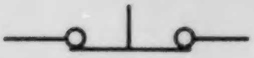
a. ______________________



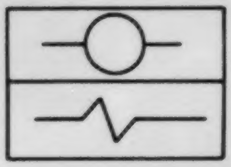
b. ______________________



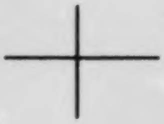
c. ______________________



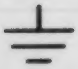
d. ______________________



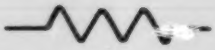
e. ______________________



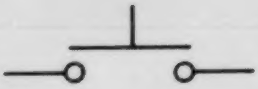
f. ______________________



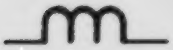
g. ______________________



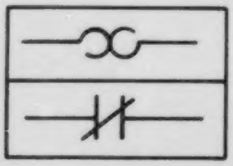
h. ______________________



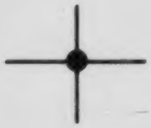
i. ______________________



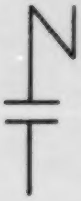
j. ______________________



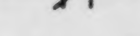
k. ______________________



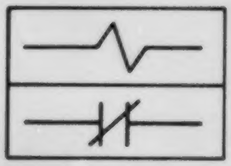
l. ______________________



m. ______________________

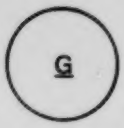


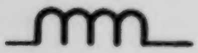
n. ______________________



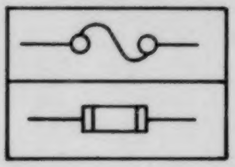
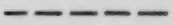
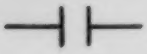
o. ______________________

TEST





p. ____________ q. ____________ r. ____________

s. ____________ t. ____________ u. ____________

3. Match abbreviations associated with direct current motor controls to their correct interpretations. Write the correct numbers in the blanks. Abbreviations and interpretations are continued on the following page.

_____a. Timed opening

_____b. Under voltage

_____c. Push button

_____d. Terminal lead

_____e. Antiplugging

_____f. Normally open

_____g. Counter electromotive force

_____h. Shunt field

_____i. Coil or contact

_____j. Field accelerating relay

_____k. Terminal line screw connection

_____l. Accelerating relay

_____m. Brake contactor

1. AP
2. C
3. T
4. cemf
5. AR
6. NO
7. B
8. FA
9. UV
10. TO
11. L
12. F
13. PB

TEST

______n.	Voltage relay	14.	VR
______o.	Timed closing	15.	FF
______p.	Armature; accelerating contactor	16.	A
______q.	Overload	17.	TC
______r.	Main line operating coil of contactor	18.	CR
______s.	Contactor coil for starting resistors	19.	S
______t.	Normally closed	20.	SR
______u.	Series field	21.	NC
______v.	Field failure	22.	DR
______w.	Time-delay relay	23.	HA
______x.	Decelerating relay	24.	OL
______y.	Control relay	25.	TR
______z.	Series relay	26.	M

4. Explain the difference between a motor starter and a motor controller.

Motor starter — ____

____

____

Motor controller — ____

____

____

5. Explain why starting resistance is needed in large direct current motors.

____

____

____

TEST

6. Name the classes of motor starters and controllers.

   a. Operation

      1) ____________________

      2) ____________________

   b. Construction

      1) ____________________

      2) ____________________

   c. Enclosure type

      1) ____________________

      2) ____________________

   d. Number of terminals

      1) ____________________

      2) ____________________

      3) ____________________

7. Name types of acceleration control provided by motor starters and controllers.

   a. ____________________

   b. ____________________

   c. ____________________

8. Match types of timers to their correct uses. Write the correct numbers in the blanks.

   _____a. Sets mechanical contacts or triggers solid-state switching device; controlled by a capacitor

   _____b. Delays closing of direct current contacts after circuit is energized

   _____c. Closes contacts according to voltage potential

   _____d. Forces air through a small hole to delay armature's motion after coil is energized

   1. Induction
   2. Capacitor
   3. Electronic
   4. Pneumatic

TEST

9. Select from the following list characteristics of across-the-line controllers. Write an "X" in the blank before each correct answer.

_____a. Motor connected directly across full-line voltage

_____b. Cause motor to accelerate slowly

_____c. Are used on large direct current motors of 5 horsepower or above

_____d. Do not have starting resistors to limit high current during starting period

_____e. Have starting resistors that limit high current during starting period

_____f. Are used on small direct current motors of 1 horsepower or below

10. Describe counter electromotive force in a direct current motor from start to run.

____

____

____

____

11. Arrange in order the sequence of operation of a counter electromotive force time-limit acceleration starter. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. As the motor accelerates, counter electromotive force builds up in the armature

_____b. The acceleration circuit is set to operate at a current value that corresponds to 100 percent of the full-load current

_____c. The voltage drop across the armature increases with speed until the relay coil of the acceleration circuit is strong enough to pull in, closing its contacts and shorting out the starting resistors

_____d. The moment the start button is pushed, counter electromotive force equals zero

12. Arrange in order the sequence of operation of a voltage-drop current-limit acceleration starter. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. When the voltage drop across the starting resistors decreases to a predetermined value, contactors A1, A2 and A3 outpull the HA relays in sequence

TEST

______b. The high starting current causes a voltage drop across the starting resistors, which allows relay HA to hold against the pull of relay A1, permitting the motor to accelerate with the starting resistor in series with the armature

______c. Closing contactors A1, A2 and A3 then close main contacts A1, A2, and A3 in sequence, connecting the motor directly across the line

______d. When the start button is depressed, the M contact closes

______e. As the motor gains speed, current through the armature circuit decreases, and the voltage drop across the starting resistors decreases

13. Explain the purpose of a mechanical interlock on forward and reverse contactors.

____

____

14. Arrange in order the sequence of operation of a single-coil series-lockout starter. Write a "1" before the first step, a "2" before the second step, and so on.

______a. Current then goes through lockout coil and armature circuit to negative line or L2

______b. Main contacts close and circuit is formed from positive line through lockout coil, resistance, and armature circuit to negative line

______c. After initial high current has decreased and motor has accelerated, current through coil permits accelerating contacts A1, A2, and A3 to close, cutting out resistance

______d. Start button is depressed

15. Arrange in order the sequence of operation of a double-coil series-lockout starter. Write a "1" before the first step, a "2" before the second step, and so on. Steps are continued on the following page.

______a. A1 contactor closes A1 contact, cutting out R1 resistor

______b. Armature in series field is directly across the line

______c. A3 and HA3 contactors close A3 contact and cut out R3 resistor

______d. M coil is energized, closing M contacts and putting armature and series field in series with starting resistors and contactors A1 and HA1

______e. Start button is depressed

______f. A2 and HA2 contactors close A2 contact and cut out R2 resistor

TEST

16. Arrange in order the sequence of operation of a series relay acceleration starter. Write a "1" before the first step, a "2" before the second step, and so on.

______a. SR3 to A3 coil is energized, closing A3 contacts and cutting out R3 resistor

______b. Start button is depressed

______c. A1 coil is energized, completing the circuit through SR1, closing A1 contacts, and cutting out R1 resistor

______d. Armature in series field is directly across the line and, based on load attached to motor, accelerates to a normal speed

______e. A2 coil is energized, completing the circuit through SR2, closing A2 contacts, and cutting out R2 resistor

______f. M coil is energized, closing M contacts and putting armature and series field in series with starting resistors and A1 contactor

17. Match methods of electrical braking to their correct descriptions. Write the correct numbers in the blanks.

______a. Line voltage or phase sequence is reversed; motor develops retarding force

______b. Energy of inertia and gravity causes motor to act as generator and retards or stops motor; power generated can be fed back into circuit

______c. Motor used like generator stops the revolving stator field; an energy-dissipating resistor is applied to the armature

1. Dynamic
2. Plug
3. Regenerative

18. Select from the following list operating characteristics of a series brake. Write an "X" in the blank before each correct answer.

______a. Is large and may not release if current through series coil is not high enough

______b. Will release at 40 percent of full-load armature current if designed for intermittent duty

TEST

______c. Has spring that mechanically sets brake

______d. Will release at 60 percent of full-load armature current if designed for intermittent duty

______e. Current sets brake

______f. Will release at 80 percent of full-load armature current if designed for continuous duty

______g. Will release at 60 percent of full-load armature current if designed for continuous duty

______h. Provides fast operation and positive braking action if armature circuit becomes open

______i. Will release at 80 percent of full-load armature current if designed for intermittent duty

______j. Needs 10 percent of full-load armature current to maintain brake release

______k. Needs pads replaced every 10,000 hours of operation

19. Select from the following list operating characteristics of a shunt brake. Write an "X" in the blank before each correct answer.

______a. Releases at 40 percent of line voltage

______b. Is fast acting

______c. Releases at approximately 80 percent of line voltage

______d. Is commonly used on heavy loads

______e. Coils are wound for one-tenth to one-half of line voltage to increase its operating speed

______f. Is slow acting due to low inductance of shunt coil

______g. Is slow-acting due to high inductance of shunt coil

TEST

_____h. Is used more often than series brake because it is more effective on widely varying and light loads

(NOTE: Test questions 20-23 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

20. Draw internal and external connections for a four-point starter and compound motor.

21. Complete a panel wiring diagram of a counter electromotive force motor controller.

22. Complete a panel wiring diagram of a voltage-drop current-limit acceleration controller.

23. Demonstrate the ability to

    a. Connect a manual three-point starter box to a direct current motor.

    b. Connect a three-point starter box and reversing switch in the armature circuit of a shunt motor.

    c. Connect a four-point starter box to a shunt motor.

    d. Connect a counter electromotive force controller to a direct current compound motor.

    e. Connect a drum controller to a direct current compound motor.

    f. Use a multimeter and schematic diagram to troubleshoot a direct current controller.

DC MOTOR CONTROL
UNIT II

ANSWERS TO TEST

1.	a.	1	h.	8	o.	11
	b.	4	i.	5	p.	16
	c.	9	j.	14	q.	18
	d.	7	k.	12	r.	20
	e.	3	l.	17	s.	13
	f.	6	m.	19	t.	15
	g.	2	n.	10		

2. a. Mechanical interlock
   b. Armature
   c. Variable resistor
   d. Single-circuit push button, NC
   e. Coil
   f. Wiring not connected
   g. Ground
   h. Fixed resistor
   i. Single-circuit push button, NO
   j. Series field
   k. Thermal overload relay
   l. Wiring connected
   m. Blowout coil
   n. Relay with normally closed contacts
   o. Magnetic overload relay

ANSWERS TO TEST

p. DC generator

q. Shunt field

r. Wiring terminal

s. Power or control fuse

t. Mechanical connection

u. Relay with normally open contacts

3.

a.	10	h.	12	o.	17	v.	15
b.	9	i.	2	p.	16	w.	25
c.	13	j.	8	q.	24	x.	22
d.	3	k.	11	r.	26	y.	18
e.	1	l.	5	s.	23	z.	20
f.	6	m.	7	t.	21		
g.	4	n.	14	u.	19		

4. Answer should include the following

   a. Motor starter — Device that limits armature current that flows when motor is first turned on; brings motor safely to its operating speed and is then switched out of circuit

   b. Motor controller — Device that combines the functions of a starter and a variable-speed control; starts, stops, reverses, changes speed, or protects motor against overheating

5. Answer should include the following

   To reduce the amount of current inrush during the start period so that there is not too great a drain on the power system

ANSWERS TO TEST

6. a. Operation
    1) Manual
    2) Automatic

   b. Construction
    1) Faceplate
    2) Drum

   c. Enclosure type
    1) Open
    2) Protected

   d. Number of terminals
    1) Two-point
    2) Three-point
    3) Four-point

7. a. Time
   b. Speed
   c. Current

8. a. 3
   b. 1
   c. 2
   d. 4

9. a, d, f

10. a. The motor's counter electromotive force is zero at the moment the motor is started

ANSWERS TO TEST

b. The only voltage drop in the armature (0 to 10 ohms) is caused by the resistance of the armature

c. The motor's counter electromotive force increases as the motor accelerates

11. a. 2 c. 3

b. 4 d. 1

12. a. 4 d. 1

b. 2 e. 3

c. 5

13. Answers should include the following — To prevent both the forward and reverse coils from being energized simultaneously

14. a. 4

b. 2

c. 3

d. 1

15. a. 3 d. 2

b. 6 e. 1

c. 5 f. 4

16. a. 5 d. 6

b. 1 e. 4

c. 3 f. 2

17. a. 2

b. 3

c. 1

ANSWERS TO TEST

18. a, b, c, f, h, j

19. c, e, g, h

20. Evaluated to the satisfaction of the instructor

21. Evaluated to the satisfaction of the instructor

22. Evaluated to the satisfaction of the instructor

23. Performance skills evaluated to the satisfaction of the instructor

INTRODUCTION TO AC MOTORS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to interpret nameplate information, determine NEMA motor dimensions and V-belt length, and adjust belt tension. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with electric motors.
2. State safety rules to be followed when working with electric motors.
3. State laws of repulsion and attraction for magnets.
4. Discuss the electron theory of magnetism.
5. Describe the role of magnets in induction motors.
6. Name types of single-phase motors.
7. Identify the parts of an open-drive motor.
8. Identify common types of motor mounts.
9. Describe types of motor enclosures.
10. Discuss operating principles of three-phase motors.
11. Name data provided on a motor nameplate.
12. List types of motor V-pulleys (sheaves).
13. Calculate load revolutions per minute and pulley diameters.
14. Describe causes of motor problems.
15. Describe remedies for motor problems.
16. Match National Electrical Manufacturers Association (NEMA) motor dimensions to their correct letter designations.
17. Interpret nameplate information.

OBJECTIVE SHEET

18. Determine National Electrical Manufacturers Association (NEMA) motor dimensions.

19. Demonstrate the ability to

    a. Determine length and taper of a V-belt.

    b. Adjust single-groove pulley V-belt tension.

INTRODUCTION TO AC MOTORS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films or slide sets on electric motor fundamentals.

B. Gather the following materials to assist you in explaining and demonstrating the procedures outlined in the information, assignment, and job sheets.

1. Various mountings and motors, including a totally enclosed fan-cooled (TEFC) motor and an open motor

2. National Safety Council posters

3. Variety of motor nameplates

4. NEMA motor dimensions charts

5. Various types of pulleys

C. Make transparencies.

D. Review "Magnetism," Unit II B, and "AC Fundamentals," Unit IV C in *Introduction to Industrial Electricity-Electronics.*

E. Provide students with objective sheet.

F. Discuss unit and specific objectives. Discuss applications for today's electrician.

G. Provide students with information, assignment, and job sheets.

H. Discuss information, assignment, and job sheets.

1. Discuss terms and definitions, using Information Sheet, Section I. Show different motors and mountings to help students relate names to motor styles.

2. Discuss safety rules for working with AC motors. Stress the danger of live voltages as well as moving parts. Information Sheet, Section II should be tested for 100 percent accuracy. Use National Safety Council posters to emphasize the need for safety.

3. Discuss magnetism and motors, using Information Sheet, Sections III through V and Transparencies #1 and #2 to emphasize the fact that induction motors rely on electromagnetic induction.

SUGGESTED ACTIVITIES

4. Discuss types of single-phase motors and their parts, using Information Sheet, Sections VI and VII and Transparency #3. Use disassembled motor to show stator, rotor, and other parts.

5. Discuss motor mounts and enclosures, using Information Sheet, Sections VIII and IX and Transparency #4. Use a TEFC motor and an open motor to show enclosure differences.

6. Discuss three-phase motors, using Information Sheet, Section X and Transparency #5. Stress the fact that most motors over 10 horsepower are three-phase motors.

7. Discuss motor nameplate information, using Information Sheet, Section XI, and Transparency #6. Assignment Sheet #1 will allow the student to interpret and record the information from a nameplate. Several different motor nameplates should be available to the students.

8. Discuss types of pulleys and methods of determining their size, using Information Sheet, Sections XII and XIII and Transparencies #7 and #8. Assignment Sheet #2 will let students figure pulley diameters and load revolutions per minute. Job Sheet #1 allows students to measure belts to accommodate pulley sizes.

9. Discuss causes and remedies of motor problems, using Information Sheet, Sections XIV and XV. Assignment Sheet #3 allows students to match remedies to problems.

10. Discuss NEMA motor dimensions using Information Sheet, Section XVI, and Transparency #9. Assignment Sheet #4 allows students to interpret the NEMA codes and information. Set up several motors to compare NEMA chart dimensions to actual motor measurements.

I. Give test.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Attraction and Repulsion of Charges

2. TM #2 — Magnetic Poles in an Electric Motor

SUGGESTED ACTIVITIES

3. TM #3 — Parts of an Open-Drive Motor
4. TM #4 — Types of Motor Mounts
5. TM #5 — Three-Phase Motor Windings
6. TM #6 — Motor Nameplate
7. TM #7 — Types of Single-Belt V-Pulleys (Sheaves)
8. TM #8 — Types of Multigroove V-Pulleys (Hubs and Sheaves)
9. TM #9 — NEMA Motor Dimensions

E. Assignment sheets

1. Assignment Sheet #1 — Interpret Nameplate Information
2. Assignment Sheet #2 — Calculate Load Revolutions per Minute and Pulley Diameters
3. Assignment Sheet #3 — Describe Remedies for Common Motor Problems
4. Assignment Sheet #4 — Determine National Electrical Manufacturers Association (NEMA) Motor Dimensions

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Determine Length and Taper of a V-Belt
2. Job Sheet #2 — Adjust Single-Groove Pulley V-Belt Tension

H. Test

I. Answers to test

III. Unit references

A. Hubert, Charles I. *Preventive Maintenance of Electrical Equipment*, 2nd ed. New York: McGraw-Hill, 1969.

B. *Motors and Generators: ANSI/NEMA Standards Publication.* Washington, D.C.: National Electrical Manufacturers Association, 1978.

SUGGESTED ACTIVITIES

C. Parady, W. Harold, J. Howard Turner, and James E. Wren. *Electric Motors.* Athens, Georgia: American Association for Vocational Instructional Materials, 1972.

D. Schweitzer, Gerald. *Basics of Fractional Horsepower Motors and Repair.* Rochelle Park, New Jersey: Hayden Book Co., 1960.

E. Turner, J. Howard. *How Electric Motors Start and Run.* Athens, Georgia: American Association for Vocational Instructional Materials, 1973.

F. Wantiez, Gary W. *Air Conditioning and Refrigeration, Book Two.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

INTRODUCTION TO AC MOTORS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Deflection — Deviation from a standard

EXAMPLE: Amount of slack in a V-belt

B. Duty rating — Evaluation for continuous or intermittent use

C. Electromagnet — Magnet created by the flow of current in insulated wire wound around a soft iron core

D. Induction motor — Alternating-current motor in which the stator is connected to the power source, thus inducing current into the rotor; there is no physical connection between the rotor and stator; instead, the motor relies on electromagnetic induction

E. National Electrical Manufacturers Association (NEMA) — Group that establishes certain voluntary standards related to motors and all electrical equipment

F. Pole — Soft, laminated iron portion of stator around which insulated wire is wound

G. Repulsion motor — Single-phase motor that incorporates a commutator and brushes

H. Resiliant mount — Rubber support on each end of motor; cushions motor base from vibrations

I. Rigid mount — Mounting brackets permanently attached to motor frame

J. Rotor — Section that rotates within the stator of a motor

K. Service factor — Indication of percentage of extra demand that can be placed on a motor

L. Shunt — Low-resistance conductor connecting two parts of a circuit in parallel

M. Slip — Difference between synchronous speed (N_s) and rotor speed (N_r)

N. Stator — Portion of an AC motor that contains the stationary parts of the magnetic circuit and their associated windings

INFORMATION SHEET

O. Synchronous speed — Constant speed to which an alternating-current motor adjusts itself

II. Safety rules to be followed when working with electric motors

A. Do not underestimate the potential danger of a 120-volt AC circuit

(NOTE: Remember that involuntary reaction to electric shock can cause you to injure yourself and possibly others.)

B. Use caution around electric arcs; they can cause bad burns to skin and eyes

C. Do not work on live circuits except when absolutely necessary

D. Never install equipment that will overload a circuit

E. Never bypass electrical protective devices

F. Make sure that all electrical circuits have proper overcurrent protection

G. Protect all electrical wires from physical and thermal hazards

H. Make sure that all electrical wiring has insulation suitable for its location and application

I. Stand on dry, nonconductive surface when working on live circuits or using electric tools

J. Check all circuits for voltage before doing any service work

K. Tag and lock electrical disconnects when working on motors or motor circuits

L. Use a ground on power tools, or use double-insulated tools

M. Use electrical cords of the proper size

N. Make sure that all tools have proper guards

O. Do not use tools with frayed or damaged cords

P. Wear eye protection

Q. Do not touch moving parts

R. Ground all electric motor frames

S. Remove jewelry such as watches and rings when performing motor work

INFORMATION SHEET

III. Laws of repulsion and attraction for magnets (Transparency #1)

  A. Like poles repel

  B. Unlike poles attract

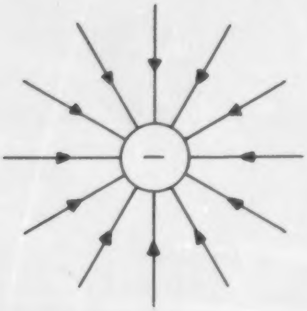
IV. Electron theory of magnetism

(NOTE: Although the forces of electricity and magnetism are related, they are completely different. Magnetic forces and electrostatic forces have no effect on one another as long as there is no motion. But, if the force field of either is set in motion, then something happens to cause the two forces to interact. This interaction — the relationship between electricity and magnetism — is explained in the electron theory of magnetism.)

  A. Electron contains negative charge that produces a force field that comes straight in to electron from all directions (Figure 1)

  EXAMPLE: Electrostatic field

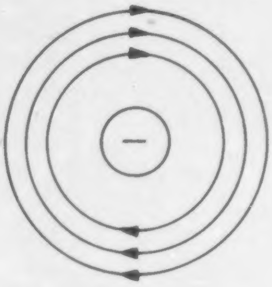
FIGURE 1



  B. Because a spinning charge produces a magnetic field, and because an electron has an orbital spin, it also contains a magnetic field, which exists in concentric circles around it (Figure 2)

  EXAMPLE: Magnetic field

FIGURE 2



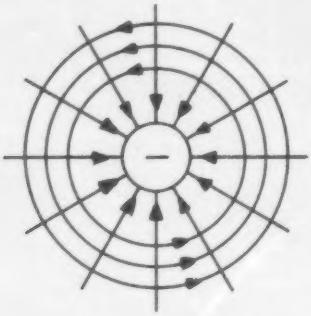
INFORMATION SHEET

C. The electrostatic and magnetic lines of force are at right angles to each other at any one point

D. The two fields combined produce an electromagnetic field (Figure 3)

EXAMPLE: Electromagnetic field

FIGURE 3



V. Role of magnets in induction motors (Transparency #2)

(NOTE: Induction motors, like synchronous motors, depend on a magnetic field for their operation. However, the induction motor does not depend on magnetic induction. Instead, it relies on electromagnetic induction.)

A. Coils wound with insulated wire create a rotating magnetic field in stator

B. Rotating magnetic field of stator induces high currents in rotor

C. Alternating direction of current flow reverses magnetic polarity of poles

(NOTE: The stator becomes an electromagnet that reverses polarity 120 times a second on 60-hertz current.)

D. The currents induced in the rotor produce their own magnetic fields, which interact with the main field to make the rotor turn

(NOTE: The rotor's permanent magnet or electromagnet turns seeking an opposite pole, and the push/pull action of attracting and repelling fields keeps the rotor turning even though there is no physical connection between the rotor and the stator. The rotor automatically adjusts to synchronous speed.)

VI. Types of single-phase motors

(NOTE: Induction motors are usually named according to the manner in which the rotating field of the stator is created.)

INFORMATION SHEET

A. Split-phase

B. Shaded-pole

C. Capacitor-start induction-run (CSIR)

D. Capacitor-start capacitor-run (CSR)

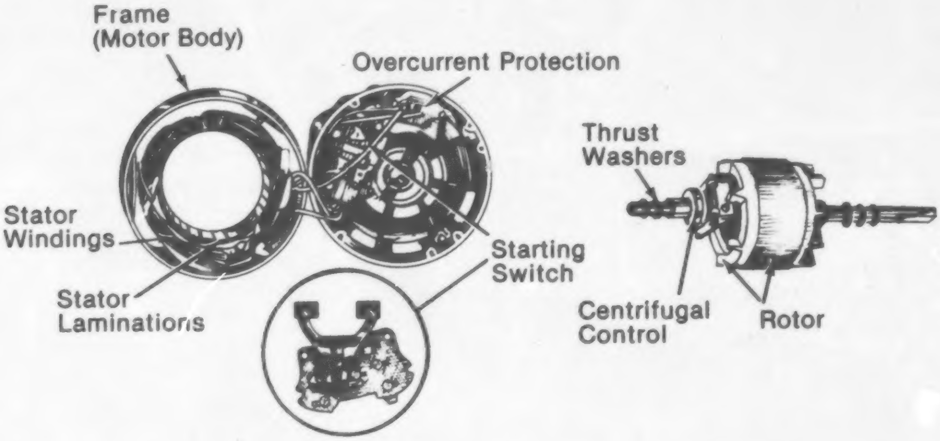
E. Permanent split capacitor (PSC)

F. Repulsion-induction

(NOTE: Repulsion-induction motors are becoming uncommon.)

VII. Parts of an open-drive motor (Figure 4; Transparency #3)

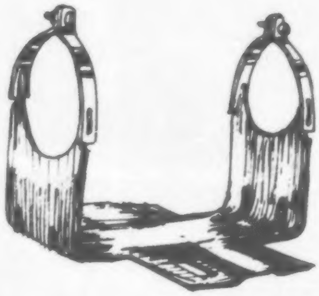
FIGURE 4


Frame (Motor Body)
Overcurrent Protection
Thrust Washers
Stator Windings
Starting Switch
Stator Laminations
Centrifugal Control
Rotor

VIII. Common types of motor mounts (Figures 5-9; Transparency #4)

A. Cradle

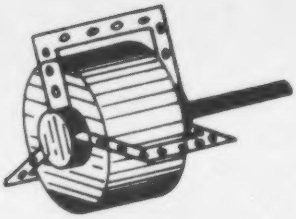
FIGURE 5



INFORMATION SHEET

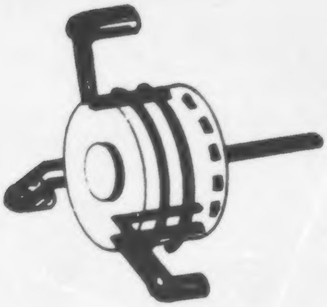
B. Blower frame

FIGURE 6



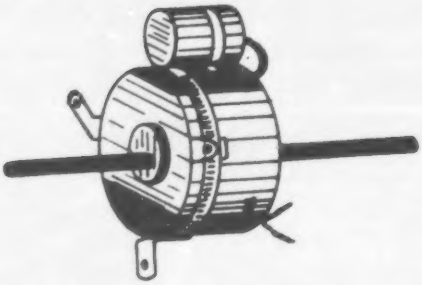
C. Three ring

FIGURE 7



D. Lug ring

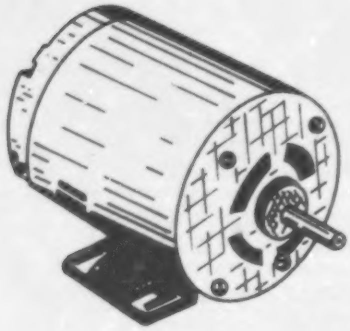
FIGURE 8



INFORMATION SHEET

E. Rigid

FIGURE 9



IX. Descriptions of types of motor enclosures

A. Open

1. Has air openings in frame and end bells

2. Is used where dirt, dust, and moisture are not a problem

B. Open drip proof

1. Has air openings in frame, with shrouds to prevent moisture from entering

2. Is used where dripping moisture may be a problem

C. Totally enclosed

(NOTE: A totally enclosed motor is *not* a sealed motor.)

1. Has no air openings

EXAMPLE: Totally enclosed fan-cooled (TEFC)

2. Is used where dust or dirt may be a problem

D. Explosion proof

1. Is constructed so that any sparking will be contained within the motor housing

2. Is used where explosive atmosphere is a problem

INFORMATION SHEET

- E. Submersible
  1. Is totally enclosed
  2. Is used where it is necessary for motor to be submersed in water or other fluid

X. Operating principles of three-phase motors (Transparency #5)

(NOTE: Three-phase motors are common in industry because they are able to start heavy loads and because electric companies supply three-phase AC power lines to industrial users on order.)

- A. Starting devices are not necessary

  EXAMPLES: Capacitors, starting switches, current relays
- B. Rotating magnetic field is generated in three phases of alternating current
- C. Each phase supplies one of three separate sets of stator poles
- D. Direction of rotation of field can be changed by reversing any two leads to stator

XI. Data provided on a motor nameplate (Transparency #6; Assignment Sheet #1)

(NOTE: Never remove the nameplate from a motor.)

- A. Model number
- B. Identification number
- C. Type
- D. Horsepower (hp)
- E. Phase (Ph or ϕ)

  (NOTE: This information refers to single-phase or three-phase current.)
- F. Hertz (Hz or cycle)
- G. Voltage (V or volts)
- H. Full-load amperage (AMP)
- I. Locked-rotor amperage (LRA)
- J. Insulation class

INFORMATION SHEET

K. Service factor (SF)

EXAMPLE: A service factor of 1.15 means that a motor can be loaded 15 percent over its rated horsepower.

L. Speed (rpm)

(NOTE: A motor's rpm indicates the revolutions per minute that the motor shaft will turn.)

M. Frame number

(NOTE: The frame will contain a NEMA-designated number indicating frame dimensions and shaft size.)

N. Ambient temperature

(NOTE: Temperature rise indicates the allowable motor temperature increase. It is usually indicated in degrees Celsius [°C].)

O. Duty rating

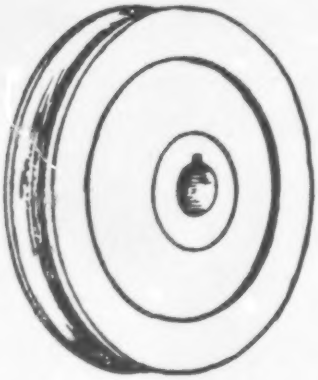
P. Internal overload information (on single-phase motors)

XII. Types of motor V-pulleys (sheaves) (Figures 10-13; Transparencies #7 and #8)

A. Single belt

EXAMPLE: Standard single belt

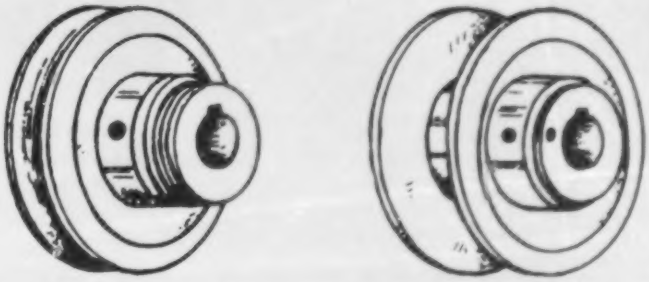
FIGURE 10



INFORMATION SHEET

EXAMPLE: Adjustable single belt

FIGURE 11

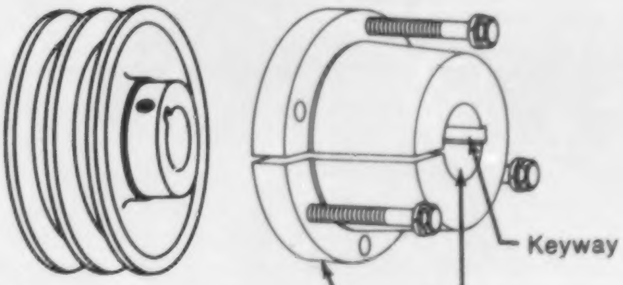


Closed   Open

B. Multigroove (hub and sheave)

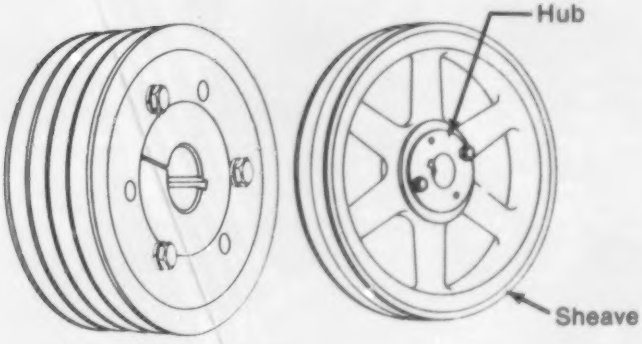
EXAMPLES:

FIGURE 12


Keyway
Shaft Opening
Hub

Assembled Hub and Sheave

FIGURE 13



Assembled Hub and Sheave

Figures 12 and 13 courtesy of Sooner Rubber Products, Oklahoma City, Oklahoma.

INFORMATION SHEET

XIII. Calculating load revolutions per minute and pulley diameters (Assignment Sheet #2)

(NOTE: Pulley diameter is always expressed in inches. Common abbreviations used in pulley diameter selection formulas include rpm [revolutions per minute], MS [motor speed], MPD [motor pulley diameter], and LPD [load pulley diameter].)

A. To calculate load revolutions per minute, use the formula Load rpm = (MS × MPD) ÷ LPD

EXAMPLE: What is the load rpm for a motor with a 6-inch motor pulley, a 10-inch load pulley, and a motor speed of 1,725 rpm?

Load rpm = (MS × MPD) ÷ LPD

= (1,725 × 6) ÷ 10

= 10,350 ÷ 10

= 1,035 rpm

B. To calculate load pulley diameter, use the formula LPD = (MS × MPD) ÷ Load rpm

EXAMPLE: What is the load pulley diameter for a motor with a 4-inch motor pulley, a motor speed of 1,800 rpm, and a load rpm of 1,725?

LPD = (MS × MPD) ÷ Load rpm

= (1,800 × 4) ÷ 1,725

= 7,200 ÷ 1,725

= 4.17 inches

C. To calculate motor pulley diameter, use the formula MPD = (Load rpm × LPD) ÷ MS

EXAMPLE: What is the motor pulley diameter for a motor with a 12-inch load pulley diameter, a motor speed of 3,500 rpm, and a load rpm of 2,125?

MPD = (Load rpm × LPD) ÷ MS

= (2,125 × 12) ÷ 3,500

= 25,500 ÷ 3,500

= 7.28 inches

INFORMATION SHEET

XIV. Causes of motor problems (Assignment Sheet #3)

A. Failure to start

1. Blown fuse or open circuit breaker
2. Low voltage or no voltage
3. Open wiring circuit
4. Incorrect power line connection
5. Excessive load
6. Excessive end play
7. Seized or worn bearings
8. Open overload

B. Excessive noise

1. Unbalanced parts

   EXAMPLES: Bearings, pulley, rotor

2. Bent shaft
3. Loose parts
4. Faulty alignment
5. Worn bearings
6. Dirt in air gap between rotor and stator
7. Uneven air gap
8. Shorted silicon-controlled rectifier (SCR) drive unit

C. Overheated bearings

1. Lack of oil
2. Dirty oil
3. Oil not reaching shaft
4. Excessive grease or oil

INFORMATION SHEET

5. Excessive belt tension
6. Rough bearing surface
7. Bent shaft
8. Misalignment of shaft and bearing
9. Excessive end thrust
10. Excessive side pull
11. Belt slippage

D. Overheated motor

1. Obstruction of ventilating system
2. Overloading
3. Rotor dragging on stator
4. Incorrect voltage
5. High ambient temperature

E. Burned out rotor or stator

1. Worn bearings
2. Moisture
3. Acids or alkalies
4. Accumulation of excessive conductive dust
5. Overloading
6. Defective start mechanism

XV. Remedies for motor problems

A. Failure to start

1. Check supply voltage

(NOTE: Supply voltage should be within 10 percent of motor nameplate voltage. If no voltage, reset breaker or check fuses.)

INFORMATION SHEET

2. Check motor wiring with ohmmeter

3. Remove load from motor and try to start

4. Move motor shaft by hand to check for end play, side play, and bearing tightness

B. Excessive noise

1. Replace out-of-balance pulley

2. Remove pulley and check straightness of shaft

3. Tighten motor accessories and mounting

4. Align drive pulley with driven pulley

5. Replace bearings

6. Clean motor

7. Check for out-of-round motor

C. Overheated bearings

1. Use recommended nondetergent motor-bearing oil

2. Put clean oil in reservoir

   (NOTE: This will be possible only on large motors with bearing oil reservoirs.)

3. Clean excessive grease buildup from ball bearings

4. Adjust belt to proper tension

5. Move motor shaft by hand to check for end play, side play, and bearing tightness

6. Replace rough or worn bearings

7. Remove pulley and check for bent shaft

8. Align drive pulley with driven pulley

INFORMATION SHEET

D. Overheated motor

  1. Clean motor

  2. Adjust belt tension

  3. Check full-load amperage

  4. Check for correct voltage

     (NOTE:A voltage check should be made at the motor terminals with the motor under load.)

  5. Check for loose bearings

  6. Check for tight bearings

  7. Check pulley alignment

  8. Remove pulley and check for bent shaft

E. Burned out rotor or stator

  1. Have stator rewound

  2. Replace rotor

  3. Replace complete motor

XVI. National Electrical Manufacturers Association (NEMA) motor dimensions (Transparency #9; Assignment Sheet #4)

A. A — Maximum base width

B. B — Maximum base length

C. D — Shaft center from lower edge of base

D. E — Mounting hole center to shaft center

E. F — Mounting hole center to frame center

   (NOTE: NEMA tables give figures for 2F or twice this dimension)

F. BA — Mounting hole center to collar of shaft at end plate

G. H — Diameter of holes in mounting base

H. N - W — Overall shaft length minus shaft collar width

I. U — Shaft diameter

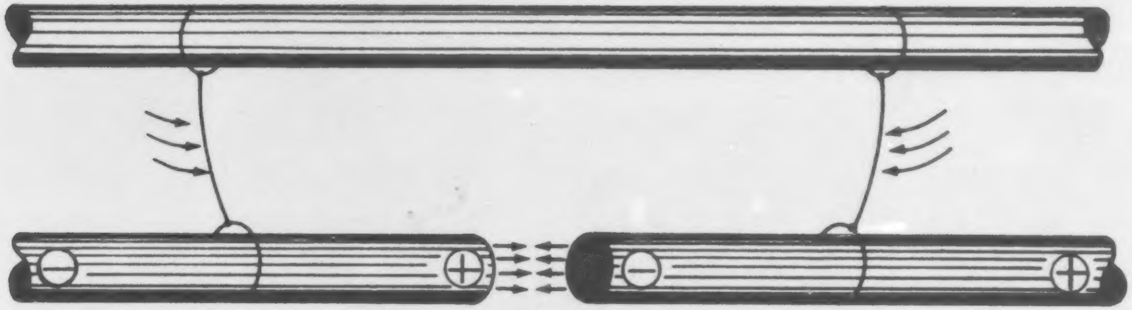
INFORMATION SHEET

J. V — Minimum mounting distance for pulley or sprocket

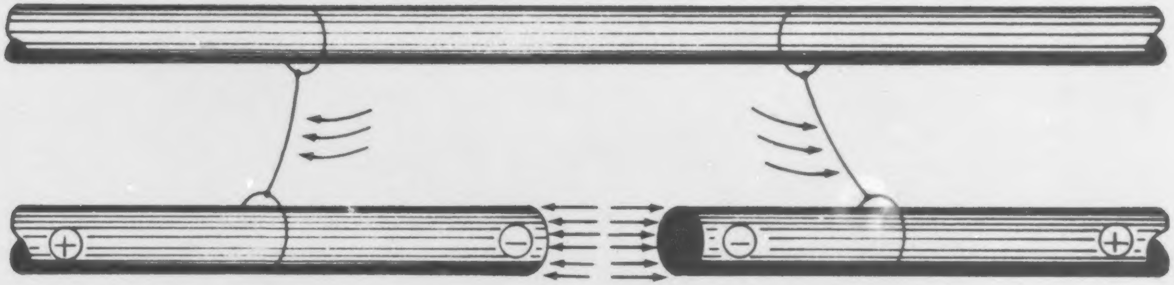
K. S — Keyway width

L. ES — Keyway length

Attraction and Repulsion of Charges

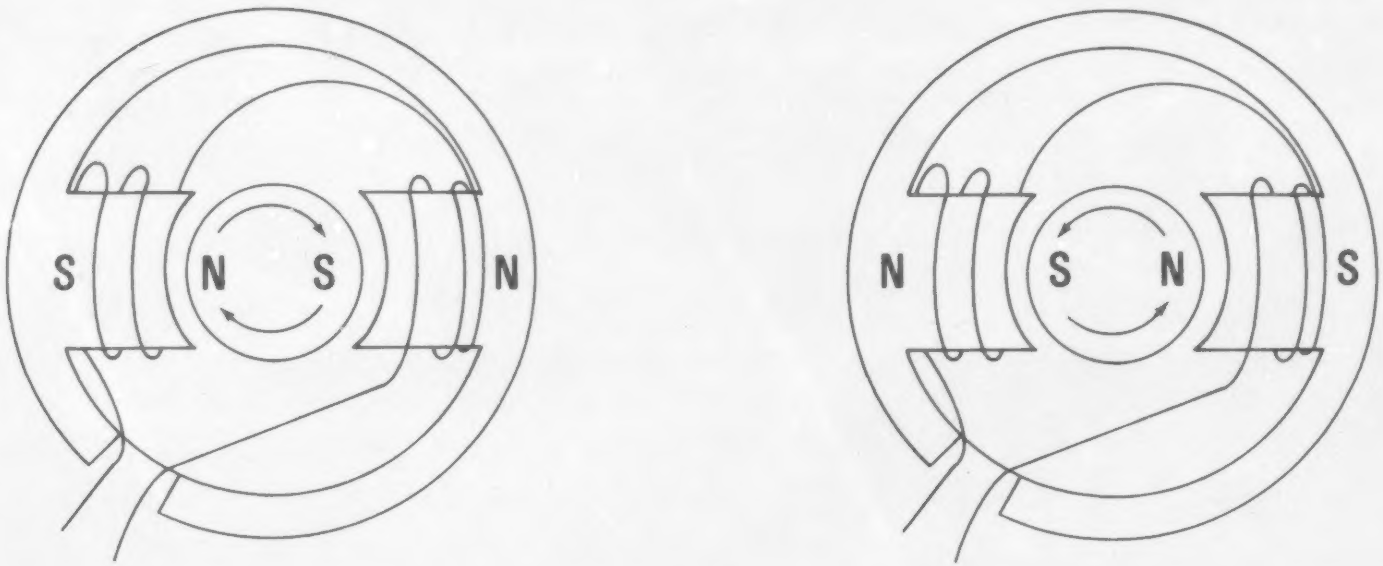


⊕ ⊖ **Charges Attract**



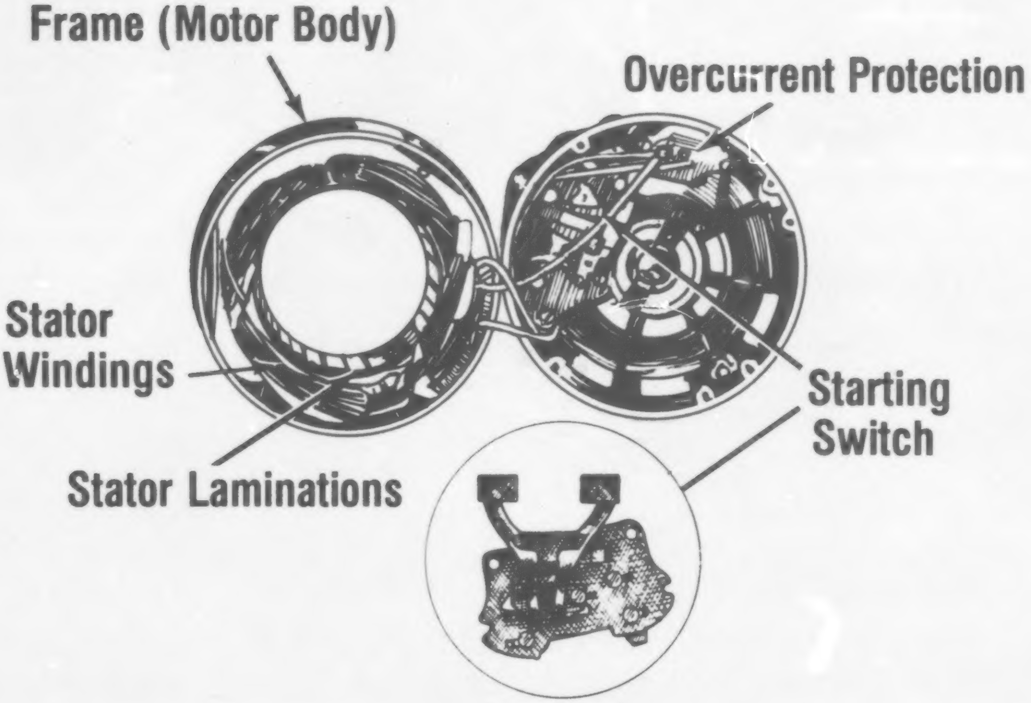
⊕ ⊕ or ⊖ ⊖ **Charges Repel**

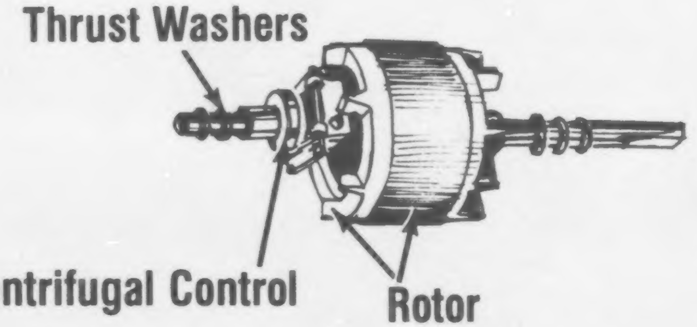
Magnetic Poles in an Electric Motor



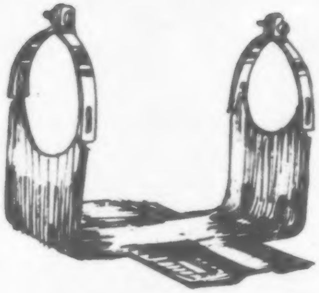
Reversing Direction of Current Flow Reverses Magnetic Polarity of Poles

Parts of an Open-Drive Motor

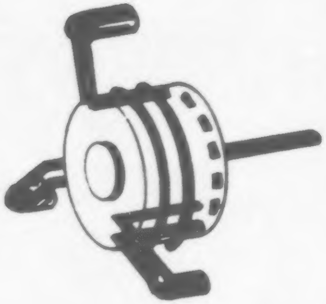

Frame (Motor Body)
Overcurrent Protection
Stator Windings
Starting Switch
Stator Laminations


Thrust Washers
Centrifugal Control
Rotor

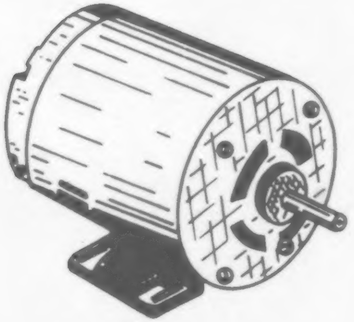
Types of Motor Mounts



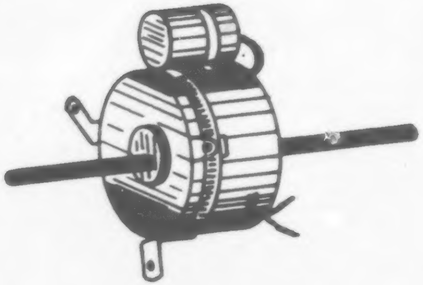
Cradle



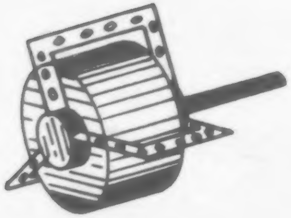
Three Ring



Rigid Mount

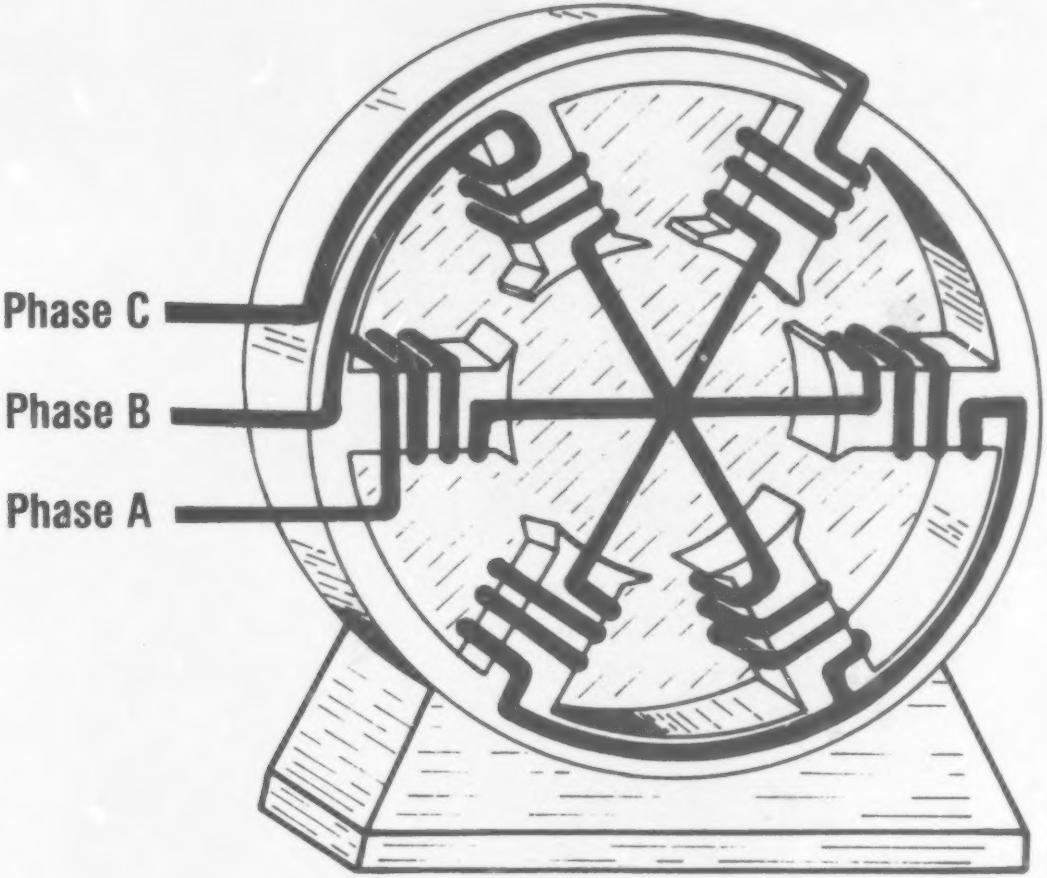


Lug Ring

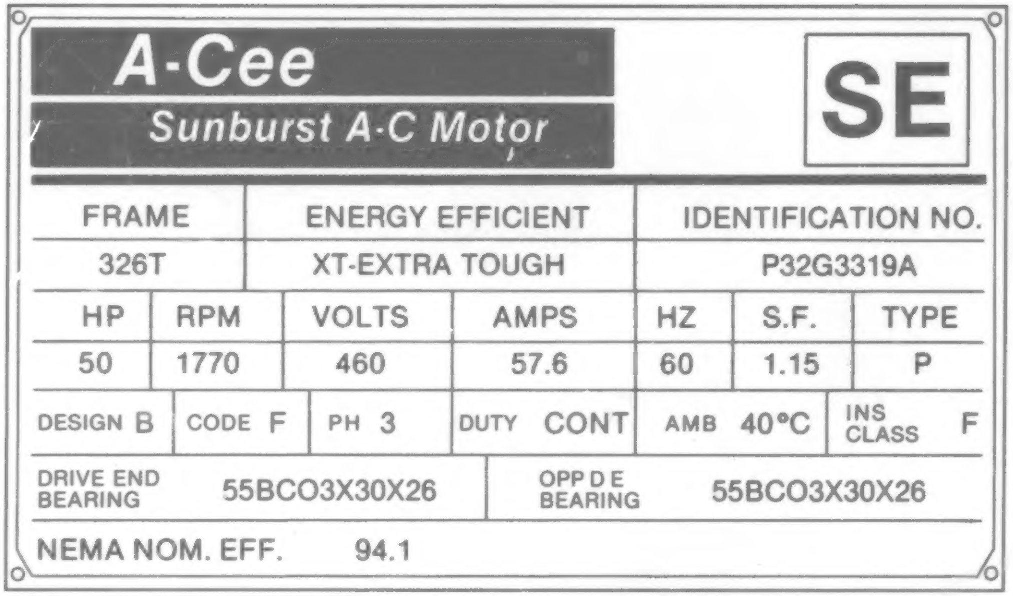


Blower Frame

Three-Phase Motor Windings


Phase C
Phase B
Phase A

Motor Nameplate



A-Cee

Sunburst A-C Motor

SE

FRAME	ENERGY EFFICIENT	IDENTIFICATION NO.
326T	XT-EXTRA TOUGH	P32G3319A

HP	RPM	VOLTS	AMPS	HZ	S.F.	TYPE
50	1770	460	57.6	60	1.15	P

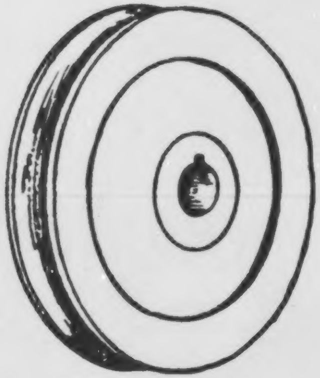
DESIGN B	CODE F	PH 3	DUTY CONT	AMB 40°C	INS CLASS F

DRIVE END BEARING	55BCO3X30X26	OPP D E BEARING	55BCO3X30X26

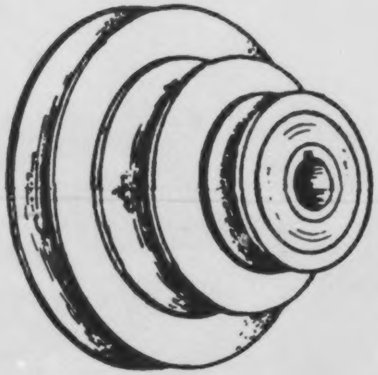
NEMA NOM. EFF. 94.1

Types of Single-Belt V-Pulleys

(Sheaves)

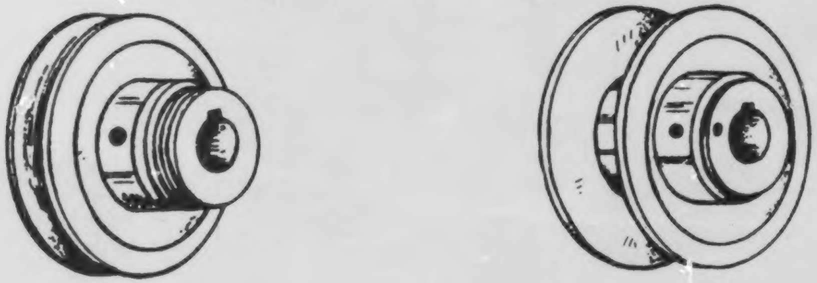


Standard Pulley



V-Step Pulley

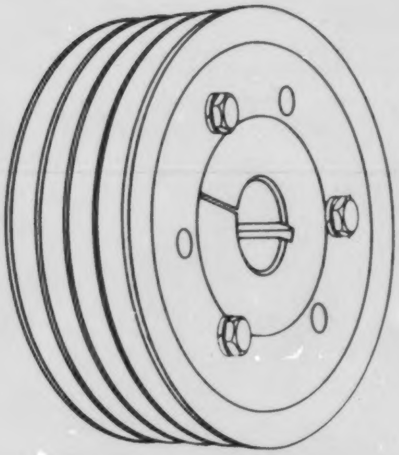
Adjustable V-Pulley



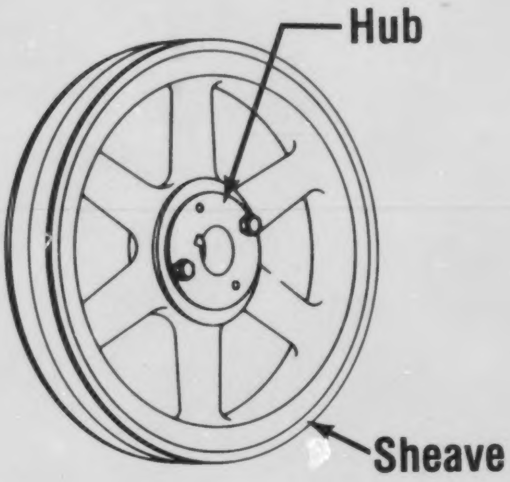
Closed

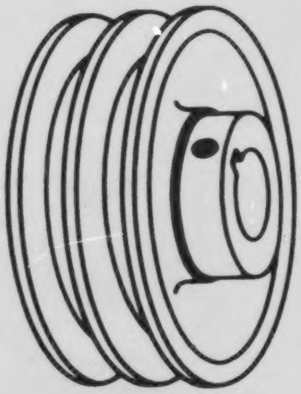
Open

Types of Multigroove V-Pulleys (Hubs and Sheaves)

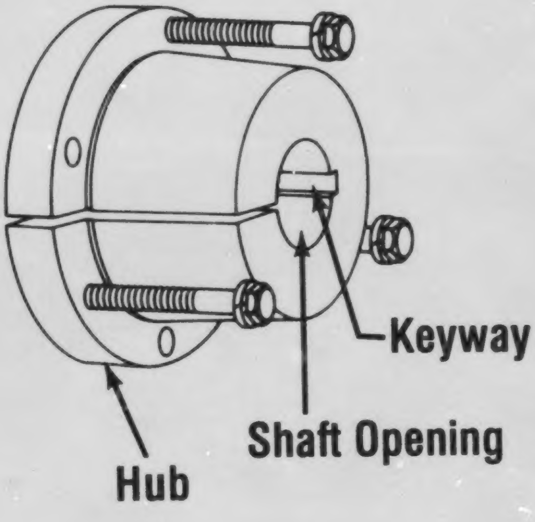


Assembled Hub and Sheave



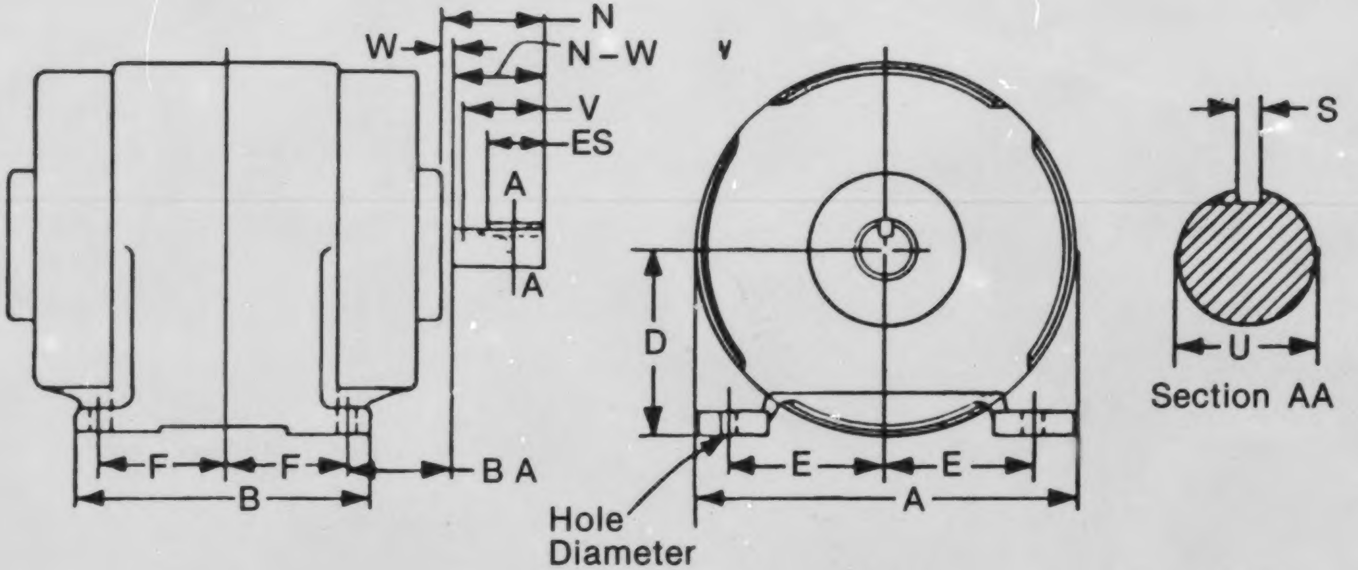


Assembled Hub and Sheave


Keyway
Shaft Opening
Hub

Courtesy of Sooner Rubber Products, Oklahoma City, Oklahoma.

NEMA Motor Dimensions


N
W
N – W
V
ES
A
A
F
F
B A
B
D
E
E
A
Hole Diameter
S
U
Section AA

Frame Designation	A	B	D	E	2F	BA	H	U	N – W	V min	ES	S
145T	7.0	6.0	3.50	2.75	5.00	2.25	0.34	0.8750	2.25	2.00	1.41	0.188
184T	9.0	7.5	4.50	3.75	5.50	2.75	0.41	1.1250	2.75	2.50	1.78	0.250
213T	10.5	7.5	5.25	4.25	5.50	3.50	0.41	1.3750	3.38	3.12	2.41	0.312

Dimensions in Inches

INTRODUCTION TO AC MOTORS
UNIT I

ASSIGNMENT SHEET #1 — INTERPRET NAMEPLATE INFORMATION

NAME ______________________________ SCORE ______________

The technician must be able to interpret motor nameplate information in order to be able to service and repair a motor.

Select an electric motor as specified by your instructor. Use the information on the nameplate to complete the following questions.

A. What is the horsepower of the motor? ______________________

B. Is this a single-phase or three-phase motor? ______________________

C. At how many revolutions per minute does the motor operate? ______________

D. What does revolutions per minute tell you about this particular motor? __________

____

E. What is the recommended voltage to which this motor should be connected? ______

F. What type of overload protection does the motor have? ______________________

G. How long is the motor designed to operate? ______________________

H. Under what temperature will the motor operate? ______________________

I. What type of enclosure does the motor have? ______________________

J. With this type of enclosure, where would you recommend using the motor? ______

____

K. What is the identification number? ______________________

L. When would you use the identification number of a motor? ______________

____

M. At how many cycles per second does the motor operate? ______________

N. What is the motor type? ______________________

O. What type of current does the motor use? ______________________

P. What is the service factor of the motor? ______________________

Q. What type of mounting is used? ______________________

INTRODUCTION TO AC MOTORS
UNIT I

ASSIGNMENT SHEET #2 — CALCULATE LOAD REVOLUTIONS PER MINUTE AND PULLEY DIAMETERS

NAME ______________________________ SCORE ______________

A service technician is sometimes called upon to change the speed of a piece of equipment. To do so, the technician must be able to calculate the pulley size needed.

Use the formulas below to solve the following problems. Remember that all fractions must be changed to decimals in order to work the formulas.

$$\text{Load rpm} = (\text{MS} \times \text{MPD}) \div \text{LPD}$$

$$\text{LPD} = (\text{MS} \times \text{MPD}) \div \text{Load rpm}$$

$$\text{MPD} = (\text{Load rpm} \times \text{LPD}) \div \text{MS}$$

A. What is load rpm of a motor with a 6-inch motor pulley diameter, a 21-inch load pulley diameter, and a motor speed of 1,725 rpm?

Load rpm = ____________________

B. What is the load rpm of a motor with an 8-inch motor pulley diameter, a 14-inch load pulley diameter, and a motor speed of 3,500?

Load rpm = ____________________

ASSIGNMENT SHEET #2

C. What is the load pulley diameter of a motor with a motor pulley diameter of 4 inches, a load rpm of 1,725, and a motor speed of 1,725 rpm?

LPD = ____________________

D. What is the load pulley diameter of a motor with a motor pulley diameter of 8 inches, a load rpm of 3,000, and a motor speed of 800 rpm?

LPD = ____________________

E. What is the motor pulley diameter of a motor with a load pulley diameter of 18 inches, a load rpm of 120, and a motor speed of 1,125 rpm?

MPD = ____________________

F. What is the motor pulley diameter of a motor with a load pulley diameter of 10 inches, a load rpm of 1,000, and a motor speed of 3,500 rpm?

MPD = ____________________

INTRODUCTION TO AC MOTORS
UNIT I

ASSIGNMENT SHEET #3 — DESCRIBE REMEDIES FOR COMMON MOTOR PROBLEMS

NAME ______________________________ SCORE ______________

A technician must be able to determine causes and remedy common motor problems.

In the following situations, the problems are stated. Write solutions for each problem. You may refer to sections XIV and XV of the Information Sheet.

A. Motor fails to start — ______________________________________

____

____

____

____

____

____

____

B. Motor is overheating — ______________________________________

____

____

____

____

____

____

____

ASSIGNMENT SHEET #3

C. Motor is excessively noisy — ______

D. Motor bearings are overheating — ______

E. Rotor or stator is burned out — ______

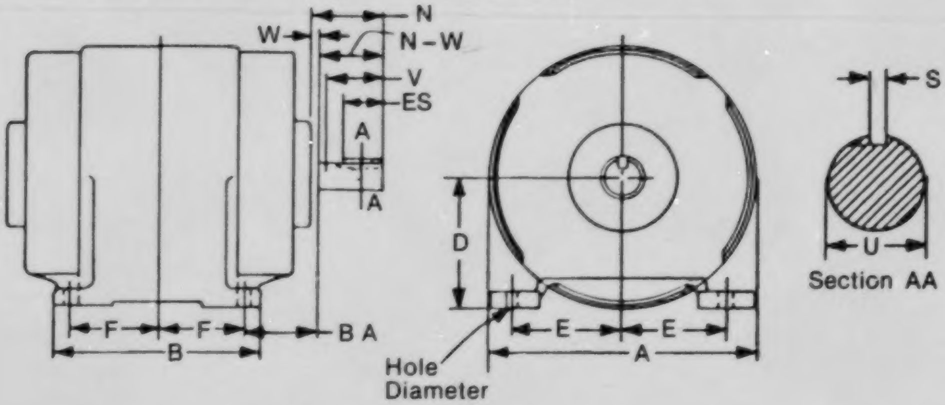
INTRODUCTION TO AC MOTORS
UNIT I

ASSIGNMENT SHEET #4 — DETERMINE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA) MOTOR DIMENSIONS

NAME ______________________________ SCORE ______________

It is important that a technician know how to use a motor dimension chart to interpret NEMA codes and information.

Practice determining NEMA dimensions by using Information Sheet, Section XVI, and Table #1 to find NEMA motor dimensions for the motor illustrated below.



A. Maximum base width (145T) ______________________________

B. Maximum base length (184T) ______________________________

C. Shaft center from lower edge of base (145T) ______________________________

D. Mounting hole center to shaft center (213T) ______________________________

E. Mounting hole center to frame center (184T) ______________________________

F. Mounting hole center to collar of shaft at end plate (213T) ______________________________

G. Diameter of holes in mounting base (184T) ______________________________

H. Overall shaft length minus shaft collar width (145T) ______________________________

I. Shaft diameter (184T) ______________________________

J. Minimum mounting distance for pulley or sprocket (213T) ______________________________

K. Keyway width (145T) ______________________________

ASSIGNMENT SHEET #4

L. Keyway length (213T) ____________________

M. Find NEMA code for motors with the following dimensions

NEMA #	Shaft Diameter	Mounting Hole Center to Shaft Center	Mounting Hole Center to Frame Center
1. __________	2.125"	6.250"	5.250"
2. __________	2.875"	8.000"	6.125"
3. __________	2.375"	9.000"	8.250"
4. __________	2.125"	8.000"	6.125"

TABLE 1

ASSIGNMENT SHEET #4

Frame Designation	A Max	B Max	D	E	2F	BA	H	U	N-W	V Min	P	Keyseat ES Min	S	AA Min
42	---	---	2.62	1.75	1.69	2.06	0.28 slot	0.3750	1.12	---	0.328	----	flat	---
48	---	---	3.00	2.12	2.75	2.50	0.34 slot	0.5000	1.50	---	0.453	---	flat	---
48H	---	---	3.00	2.12	4.75	2.50	0.34 slot	0.5000	1.50	---	0.453	---	flat	---
56	---	---	3.50	2.44	3.00	2.75	0.34 slot	0.6250	1.88	---	0.517	1.41	0.188	---
56H	---	---	3.50	2.44	5.00	2.75	0.34 slot	0.6250	1.88	---	0.517	1.41	0.188	---
143T	7.0	6.0	3.50	2.75	4.00	2.25	0.34 hole	0.8750	2.25	2.00	0.771	1.41	0.188	¾
145T	7.0	6.0	3.50	2.75	5.00	2.25	0.34 hole	0.8750	2.25	2.00	0.771	1.41	0.188	¾
182T	9.0	6.5	4.50	3.75	4.50	2.75	0.41 hole	1.1250	2.75	2.50	0.986	1.78	0.250	¾
184T	9.0	7.5	4.50	3.75	5.50	2.75	0.41 hole	1.1250	2.75	2.50	0.986	1.78	0.250	¾
213T	10.5	7.5	5.25	4.25	5.50	3.50	0.41 hole	1.3750	3.38	3.12	1.201	2.41	0.312	1
215T	10.5	9.0	5.25	4.25	7.00	3.50	0.41 hole	1.3750	3.38	3.12	1.201	2.41	0.312	1
254T	12.5	10.8	6.25	5.00	8.25	4.25	0.53 hole	1.625	4.00	3.75	1.416	2.91	0.375	1¼
256T	12.5	12.5	6.25	5.00	10.00	4.25	0.53 hole	1.625	4.00	3.75	1.416	2.91	0.375	1¼
284T	14.0	12.5	7.00	5.50	9.50	4.75	0.53 hole	1.875	4.62	4.38	1.591	3.28	0.500	1½
284TS	14.0	12.5	7.00	5.50	9.50	4.75	0.53 hole	1.625	3.25	3.00	1.416	1.91	0.375	1½
286T	14.0	14.0	7.00	5.50	11.00	4.75	0.53 hole	1.875	4.62	4.38	1.591	3.28	0.500	1½
286TS	14.0	14.0	7.00	5.50	11.00	4.75	0.53 hole	1.625	3.25	3.00	1.416	1.91	0.375	1½
324T	16.0	14.0	8.00	6.25	10.50	5.25	0.66 hole	2.125	5.25	5.00	1.845	3.91	0.500	2
324TS	16.0	14.0	8.00	6.25	10.50	5.25	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	2
326T	16.0	15.5	8.00	6.25	12.00	5.25	0.66 hole	2.125	5.25	5.00	1.845	3.91	0.500	2
326TS	16.0	15.5	8.00	6.25	12.00	5.25	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	2
364T	18.0	15.2	9.00	7.00	11.25	5.88	0.66 hole	2.375	5.88	5.62	2.021	4.28	0.625	3
364TS	18.0	15.2	9.00	7.00	11.25	5.88	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	3
365T	18.0	16.2	9.00	7.00	12.25	5.88	0.66 hole	2.375	5.88	5.62	2.021	4.28	0.625	3
365TS	18.0	16.2	9.00	7.00	12.25	5.88	0.66 hole	1.875	3.75	3.50	1.591	2.03	0.500	3
404T	20.0	16.2	10.00	8.00	12.25	6.62	0.81 hole	2..875	7.25	7.00	2.450	5.65	0.750	3
404TS	20.0	16.2	10.00	8.00	12.25	6.62	0.81 hole	2.125	4.25	4.00	1.845	2.78	0.500	3
405T	20.0	17.8	10.00	8.00	13.75	6.62	0.81 hole	2..875	7.25	7.00	2.450	5.65	0.750	3
405TS	20.0	17.8	10.00	8.00	13.75	6.62	0.81 hole	2.125	4.25	4.00	1.845	2.78	0.500	3
444T	22.0	18.5	11.00	9.00	14.50	7.50	0.81 hole	3.375	8.50	8.25	2.880	6.91	0.875	3
444TS	22.0	18.5	11.00	9.00	14.50	7.50	0.81 hole	2.375	4.75	4.50	2.021	3.03	0.625	3
445T	22.0	20.5	11.00	9.00	16.50	7.50	0.81 hole	3.375	8.50	8.25	2.880	6.91	0.875	3
445TS	22.0	20.5	11.00	9.00	16.50	7.50	0.81 hole	2.375	4.75	4.50	2.021	3.03	0.625	3

Source: *NEMA Motors and Generators*, No. 1116-1-1972, Part II, page 6.

INTRODUCTION TO AC MOTORS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1 — Evaluated to the satisfaction of the instructor

Assignment Sheet #2

A. 493 rpm

B. 2,000 rpm

C. 4.0 inches

D. 2.1 inches

E. 1.9 inches

F. 2.8 inches

Assignment Sheet #3

A. 1. Check supply voltage
   2. Check motor wiring with ohmmeter
   3. Remove load from motor and try to start
   4. Move motor shaft by hand to check for end play, side play, and bearing tightness

B. 1. Clean motor
   2. Adjust belt tension
   3. Check full-load amperage
   4. Check for correct voltage
   5. Check for loose bearings
   6. Check for tight bearings
   7. Check pulley alignment
   8. Remove pulley and check for bent shaft

ANSWERS TO ASSIGNMENT SHEETS

C.
1. Replace out-of-balance pulley
2. Remove pulley and check straightness of shaft
3. Tighten motor accessories and mounting
4. Align drive pulley with driven pulley
5. Replace bearings
6. Clean motor
7. Check for out-of-round motor

D.
1. Use recommended nondetergent motor-bearing oil
2. Put clean oil in reservoir
3. Clean excessive grease buildup from ball bearings
4. Adjust belt to proper tension
5. Move motor shaft by hand to check for end play, side play, and bearing tightness
6. Replace rough or worn bearings
7. Remove pulley and check for bent shaft
8. Align drive pulley with driven pulley

E.
1. Have stator rewound
2. Replace rotor
3. Replace complete motor

Assignment Sheet #4

A. 7.0 inches
B. 7.5 inches
C. 3.5 inches
D. 4.25 inches
E. 2.75 inches
F. 3.5 inches
G. 0.41 inch
H. 2.25 inches
I. 1.125 inches
J. 3.12 inches
K. 0.188 inches
L. 2.41 inches
M.
1. 324T
2. 404T
3. 445TS
4. 404TS

INTRODUCTION TO AC MOTORS
UNIT I

JOB SHEET #1 — DETERMINE LENGTH AND TAPER OF A V-BELT

I. Equipment and materials

A. Flexible tape measure

B. Belt-driven equipment

C. Lock and key for disconnect switch

II. Procedure

A. Disconnect and lock open the electric power circuit to belt-driven equipment

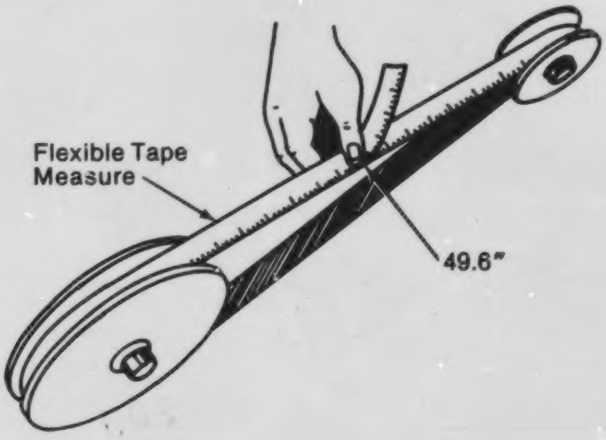
(CAUTION: Failure to lock disconnect open may be cause for dismissal from job.)

B. Check that motor is in center of its adjustment range

C. Wrap flexible tape measure around pulleys (Figure 14)

(NOTE: Be sure that the tape measure fits in the pulley grooves at the same places that the belt would fit.)

FIGURE 14



D. Read measurement

E. Round measurement to nearest full inch

JOB SHEET #1

F. Read taper style marked on pulleys

G. Record findings

Length = ______________

Taper = ______________

H. Clean work area; put away equipment and materials

INTRODUCTION TO AC MOTORS
UNIT I

JOB SHEET #2 — ADJUST SINGLE-GROOVE PULLEY V-BELT TENSION

I. Equipment and materials

- A. Combination wrench set
- B. Straightedge
- C. Ammeter
- D. Belt-driven equipment
- E. Lock and key for disconnect switch
- F. Eye protection
- G. Belt-tension gauge
- H. Appropriate service manual

II. Procedure

- A. Disconnect and lock open the electric power circuit to belt-driven equipment

  (CAUTION: Failure to lock disconnect open may be cause for dismissal from job.)

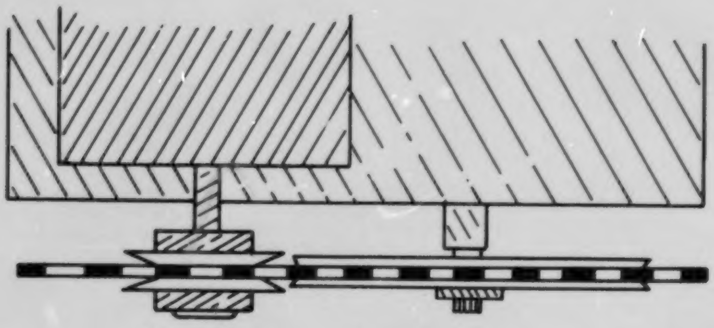
- B. Remove V-belt

JOB SHEET #2

C. Place straightedge in pulley grooves to check pulley alignment (Figure 15)

(NOTE: If pulleys do not align, loosen setscrews and align them.)

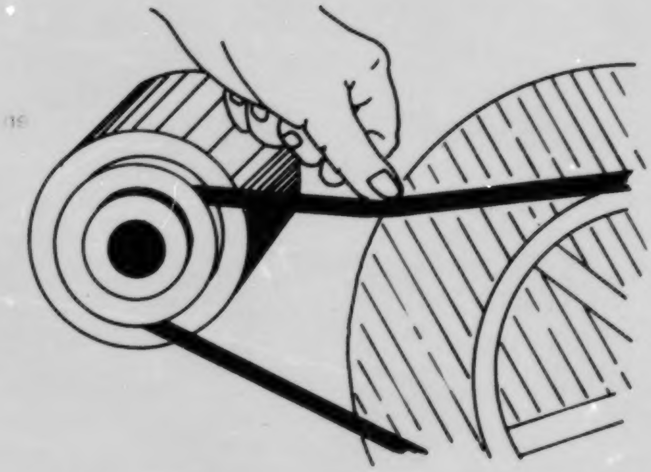
FIGURE 15



D. Replace belt

E. Press down on belt halfway between motor pulley and blower pulley (Figure 16)

FIGURE 16

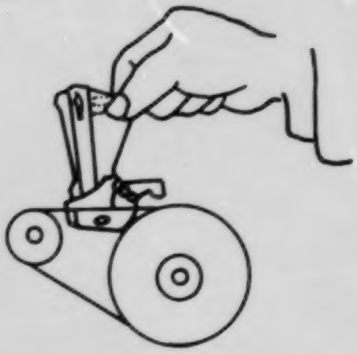


JOB SHEET #2

F. Check belt tension

(NOTE: Depending on the length of the belt, deflection will be 3/4 to 1 inch. A tension gauge is used to check belt deflection. See Figure 17. When using this type of gauge, refer to the manufacturer's recommendations for proper tension.)

FIGURE 17



G. If belt is too loose, loosen motor adjustment and tighten belt

H. Recheck tension

I. Replace any guards and panels that have been removed

(NOTE: In order to obtain an accurate amperage reading, the panels must be on the blower compartment.)

J. Reconnect electric power circuit

K. Put on eye protection

L. Start motor

M. Check amperage

(NOTE: If the amperage draw is too high, the belt is too tight.)

N. Stop motor

O. Disconnect and lock open the electric circuit to motor

P. Clean work area; put away equipment and materials

INTRODUCTION TO AC MOTORS
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct definitions terms associated with electric motors. Write the correct numbers in the blanks. Definitions are continued on the following page.

_____a. Portion of an AC motor that contains the stationary parts of the magnetic circuit and their associated windings

_____b. Alternating-current motor in which the stator is connected to the power source, thus inducing current into the rotor; there is no physical connection between the rotor and stator; instead, the motor relies on electromagnetic induction

_____c. Soft, laminated iron portion of stator around which insulated wire is wound

_____d. Single-phase motor that incorporates a commutator and brushes

_____e. Section that rotates within the stator of a motor

_____f. Constant speed to which an alternating-current motor adjusts itself

_____g. Group that establishes certain voluntary standards related to motors and all electrical equipment

_____h. Deviation from a standard

_____i. Difference between synchronous speed (N_s) and rotor speed (N_r)

_____j. Rubber support on each end of motor; cushions motor base from vibrations

_____k. Mounting brackets permanently attached to motor frame

1. Rotor
2. Pole
3. Induction motor
4. Synchronous speed
5. Repulsion motor
6. Stator
7. Deflection
8. National Electrical Manufacturers Association (NEMA)
9. Slip
10. Resilient mount
11. Rigid mount
12. Shunt
13. Service factor
14. Duty rating
15. Electromagnet

TEST

_____l. Low-resistance conductor connecting two parts of a circuit in parallel

_____m. Evaluation for continuous or intermittent use

_____n. Indication of percentage of extra demand that can be placed on motor

_____o. Magnet created by the flow of current in insulated wire wound around a soft iron core

2. State ten safety rules to be followed when working with electric motors.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

i. ____________________

j. ____________________

3. State the laws of repulsion and attraction for magnets.

a. ____________________

b. ____________________

TEST

4. Discuss the electron theory of magnetism.

5. Describe the role of magnets in induction motors.

6. Name five types of single-phase motors.

    a. __________

    b. __________

    c. __________

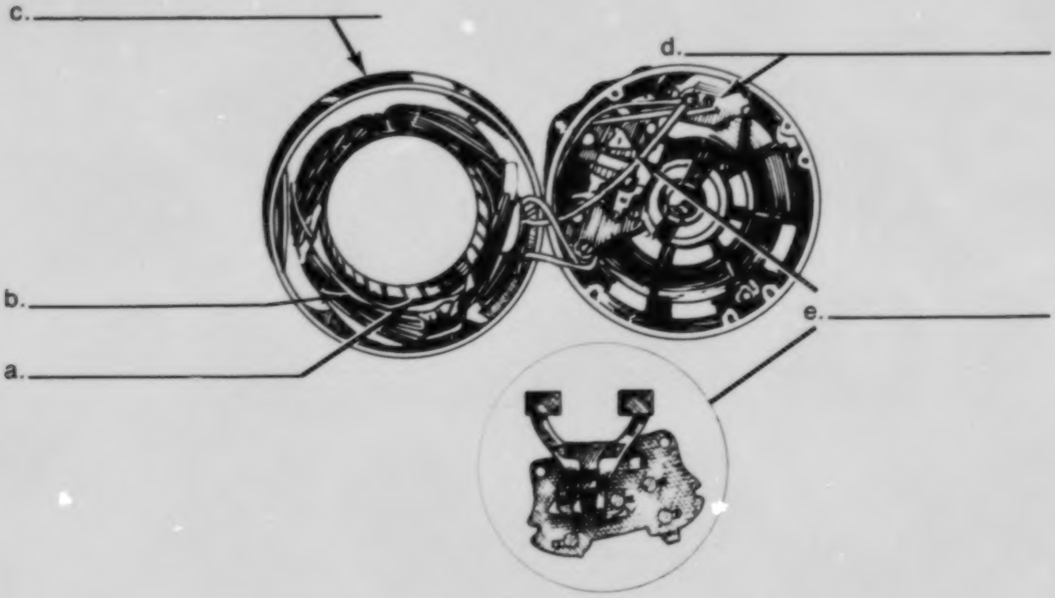
    d. __________

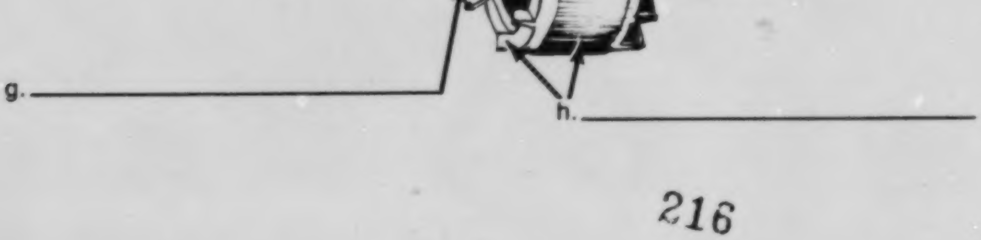
    e. __________

TEST

7. Identify the parts of an open-drive motor. Write the correct names in the blanks.

Centrifugal control
Overcurrent protection
Stator windings
Thrust washers
Stator laminations
Frame (motor body)
Rotor
Starting switch

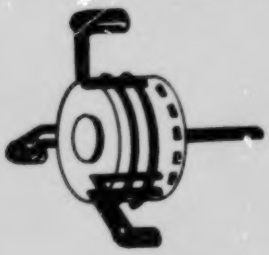




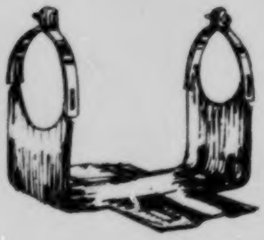
TEST

8. Identify common types of motor mounts. Write the correct names in the blanks.

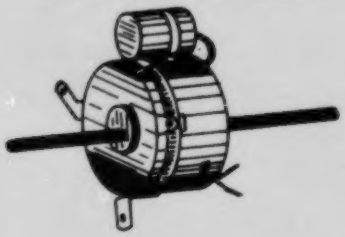
Cradle
Blower frame
Rigid
Three ring
Lug ring



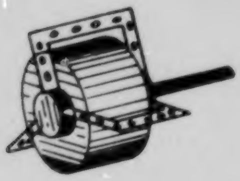
a. ______________________________



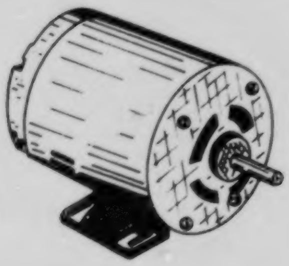
b. ______________________________



c. ______________________________



d. ______________________________



e. ______________________________

9. Describe types of motor enclosures.

a. Open — ______________________________

____

____

b. Open drip proof — ______________________________

____

____

TEST

c. Totally enclosed —

d. Explosion proof —

e. Submersible —

10. Discuss operating principles of three-phase motors.

11. Name data provided on a motor nameplate.

a.
b.
c.
d.
e.
f.
g.
h.
i.
j.

TEST

k. ____________________

l. ____________________

m. ____________________

n. ____________________

o. ____________________

p. ____________________

12. List types of motor V-pulleys (sheaves).

    a. ____________________

    b. ____________________

13. Calculate load revolutions per minute and pulley diameters for the following problems. Change fractions to decimals, and show all formulas and work.

    a. What is the load pulley diameter of a motor with a motor pulley diameter of $1\frac{3}{4}$ inches, a load rpm of 750, and a motor speed of 1,120 rpm?

       LPD = ____________________

    b. What is the load rpm of a motor with a motor pulley diameter of 2 inches, a load pulley diameter of 3 inches, and a motor speed of 1,700 rpm?

       Load rpm = ____________________

TEST

c. What is the motor pulley diameter of a motor with a load pulley diameter of 1 1/4 inches, a load rpm of 1,725, and a motor speed of 820 rpm?

MPD = ____________________

14. Describe three causes for each of the following motor problems.

a. Failure to start — ____

____

____

____

b. Excessive noise — ____

____

____

____

c. Overheated bearings — ____

____

____

____

d. Overheated motor — ____

____

____

____

TEST

e. Burned out rotor or stator — ______________________________

____

____

____

15. Describe three remedies for each of the following motor problems.

a. Failure to start — ______________________________

____

____

____

b. Excessive noise — ______________________________

____

____

____

c. Overheated bearings — ______________________________

____

____

____

d. Overheated motor — ______________________________

____

____

____

e. Burned out rotor or stator — ______________________________

____

____

____

TEST

16. Match National Electrical Manufacturers Association (NEMA) motor dimensions to their correct letter designations. Write the correct numbers in the blanks.

______a. Overall shaft length minus shaft collar width
______b. Shaft diameter
______c. Maximum base width
______d. Shaft center from lower edge of base
______e. Maximum base length
______f. Mounting hole center to shaft center
______g. Keyway length
______h. Keyway width
______i. Minimum mounting distance for pulley or sprocket
______j. Mounting hole center to frame center
______k. Mounting hole center to collar of shaft at end plate
______l. Diameter of holes in mounting base

1. A
2. B
3. D
4. E
5. F
6. BA
7. H
8. N – W
9. U
10. V
11. S
12. ES

(NOTE: Test questions 17-19 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

17. Interpret nameplate information.

18. Determine National Electrical Manufacturers Association (NEMA) motor dimensions.

19. Demonstrate the ability to

    a. Determine length and taper of a V-belt.

    b. Adjust single-groove pulley V-belt tension.

INTRODUCTION TO AC MOTORS
UNIT I

ANSWERS TO TEST

1.

a.	6	f.	4	k.	11
b.	3	g.	8	l.	12
c.	2	h.	7	m.	14
d.	5	i.	9	n.	13
e.	1	j.	10	o.	15

2. Answer should include any ten of the following

   a. Do not underestimate the potential danger of a 120-volt AC circuit

   b. Use caution around electric arcs; they can cause bad burns to skin and eyes

   c. Do not work on live circuits except when absolutely necessary

   d. Never install equipment that will overload a circuit

   e. Never bypass electrical protective devices

   f. Make sure that all electrical circuits have proper overcurrent protection

   g. Protect all electrical wires from physical and thermal hazards

   h. Make sure that all electrical wiring has insulation suitable for its location and application

   i. Stand on dry, nonconductive surface when working on live circuits or using electric tools

   j. Check all circuits for voltage before doing any service work

   k. Tag and lock electrical disconnects when working on motors or motor circuits

   l. Use a ground on power tools, or use double-insulated tools

   m. Use electrical cords of the proper size

   n. Make sure that all tools have proper guards

   o. Do not use tools with frayed or damaged cords

ANSWERS TO TEST

p. Wear eye protection

q. Do not touch moving parts

r. Ground all electric motor frames

s. Remove jewelry such as watches and rings when performing motor work

3. a. Like poles repel

   b. Unlike poles attract

4. Discussion should include the following

   a. Electron contains negative charge that produces a force field that comes straight in to electron from all directions

   b. Because a spinning charge produces a magnetic field, and because an electron has an orbital spin, it also contains a magnetic field, which exists in concentric circles around it

   c. The electrostatic and magnetic lines of force are at right angles to each other at any one point

   d. The two fields combined produce an electromagnetic field

5. Description should include the following

   a. Coils wound with insulated wire create a rotating magnetic field in stator

   b. Rotating magnetic field of stator induces high currents in rotor

   c. Alternating direction of current flow reverses magnetic polarity of poles

   d. The currents induced in the rotor produce their own magnetic fields, which interact with the main field to make the rotor turn

6. Answer should include any five of the following

   a. Split-phase

   b. Shaded-pole

   c. Capacitor-start induction-run (CSIR)

ANSWERS TO TEST

- d. Capacitor-start capacitor-run (CSR)
- e. Permanent split capacitor (PSC)
- f. Repulsion-induction

7. a. Stator laminations
   - b. Stator windings
   - c. Frame (motor body)
   - d. Overcurrent protection
   - e. Starting switch
   - f. Thrust washers
   - g. Centrifugal control
   - h. Rotor

8. a. Three ring
   - b. Cradle
   - c. Lug ring
   - d. Blower frame
   - e. Rigid

9. Description should include the following
   - a. Open
     - 1) Has air openings in frame and end bells
     - 2) Is used where dirt, dust, and moisture are not a problem
   - b. Open drip proof
     - 1) Has air openings in frame, with shrouds to prevent moisture from entering
     - 2) Is used where dripping moisture may be a problem

ANSWERS TO TEST

- c. Totally enclosed
    - 1) Has no air openings
    - 2) Is used where dust or dirt may be a problem
- d. Explosion proof
    - 1) Is constructed so that any sparking will be contained within the motor housing
    - 2) Is used where explosive atmosphere is a problem
- e. Submersible
    - 1) Is totally enclosed
    - 2) Is used where it is necessary for motor to be submersed in water or other fluid

10. Discussion should include the following
    - a. Starting devices are not necessary
    - b. Rotating magnetic field is generated in three phases of alternating current
    - c. Each phase supplies one of three separate sets of stator poles
    - d. Direction of rotation of field can be changed by reversing any two leads to stator

11. a. Model number
    - b. Identification number
    - c. Type
    - d. Horsepower (hp)
    - e. Phase (Ph or ϕ)
    - f. Hertz (Hz or cycle)
    - g. Voltage (V or volts)
    - h. Full-load amperage (AMP)
    - i. Locked-rotor amperage (LRA)

ANSWERS TO TEST

- j. Insulation class
- k. Service factor (SF)
- l. Speed (rpm)
- m. Frame number
- n. Ambient temperature
- o. Duty rating
- p. Internal overload information (on single-phase motors)

12. a. Single belt
    b. Multigroove (hub and sheave)

13. a. 2.61 inches
    b. 1,133 rpm
    c. 2.62 inches

14. Description should include any three of the following under each section
    a. Failure to start
        1) Blown fuse or open circuit breaker
        2) Low voltage or no voltage
        3) Open wiring circuit
        4) Incorrect power line connection
        5) Excessive load
        6) Excessive end play
        7) Seized or worn bearings
        8) Open overload
    b. Excessive noise
        1) Unbalanced parts

ANSWERS TO TEST

    2) Bent shaft
    3) Loose parts
    4) Faulty alignment
    5) Worn bearings
    6) Dirt in air gap between rotor and stator
    7) Uneven air gap
    8) Shorted silicon-controlled rectifier (SCR) drive unit

c. Overheated bearings

    1) Lack of oil
    2) Dirty oil
    3) Oil not reaching shaft
    4) Excessive grease or oil
    5) Excessive belt tension
    6) Rough bearing surface
    7) Bent shaft
    8) Misalignment of shaft and bearing
    9) Excessive end thrust
    10) Excessive side pull
    11) Belt slippage

d. Overheated motor

    1) Obstruction of ventilating system
    2) Overloading
    3) Rotor dragging on stator
    4) Incorrect voltage
    5) High ambient temperature

ANSWERS TO TEST

- e. Burned out rotor or stator
    - 1) Worn bearings
    - 2) Moisture
    - 3) Acids or alkalies
    - 4) Accumulation of excessive conductive dust
    - 5) Overloading
    - 6) Defective start mechanism

15. Answer should include any three of the following under each section

- a. Failure to start
    - 1) Check supply voltage
    - 2) Check motor wiring with ohmmeter
    - 3) Remove load from motor and try to start
    - 4) Move motor shaft by hand to check for end play, side play, and bearing tightness
- b. Excessive noise
    - 1) Replace out-of-balance pulley
    - 2) Remove pulley and check straightness of shaft
    - 3) Tighten motor accessories and mounting
    - 4) Align drive pulley with driven pulley
    - 5) Replace bearings
    - 6) Clean motor
    - 7) Check for out-of-round motor
- c. Overheated bearings
    - 1) Use recommended nondetergent motor-bearing oil
    - 2) Put clean oil in reservoir

ANSWERS TO TEST

3) Clean excessive grease buildup from ball bearings

4) Adjust belt to proper tension

5) Move motor shaft by hand to check for end play, side play, and bearing tightness

6) Replace rough or worn bearings

7) Remove pulley and check for bent shaft

8) Align drive pulley with driven pulley

d. Overheated motor

1) Clean motor

2) Adjust belt tension

3) Check full-load amperage

4) Check for correct voltage

5) Check for loose bearings

6) Check for tight bearings

7) Check pulley alignment

8) Remove pulley and check for bent shaft

e. Burned out rotor or stator

1) Have stator rewound

2) Replace rotor

3) Replace complete motor

16.	a.	8	e.	2	i.	10
	b.	9	f.	4	j.	5
	c.	1	g.	12	k.	6
	d.	3	h.	11	l.	7

ANSWERS TO TEST

17. Evaluated to the satisfaction of the instructor

18. Evaluated to the satisfaction of the instructor

19. Performance skills evaluated to the satisfaction of the instructor

SHADED-POLE MOTORS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to check a shaded-pole motor. The student will show this knowledge by completing the job sheet and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Define terms associated with shaded-pole motors.
2. Name applications of shaded-pole motors.
3. Describe stator construction of shaded-pole motors.
4. Match number of poles to their correct motor speeds.
5. Name disadvantages of shaded-pole motors.
6. Name voltages for shaded-pole motors.
7. Describe methods of reversing rotation of shaded-pole motors.
8. Describe methods of changing speed in shaded-pole motors.
9. State the most common remedy for shaded-pole motor failure.
10. Demonstrate the ability to check a shaded-pole motor.

SHADED-POLE MOTORS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Discuss unit and specific objectives. State need for knowledge in each area.

   D. Provide students with information and job sheets.

   E. Discuss information and job sheets.

      1. Discuss terms and definitions, using Information Sheet, Section I. Have disassembled motor to show parts given in terms.

      2. Discuss application of shaded-pole motors, using Information Sheet, Section II. Point out the number of appliances in use today that incorporate a shaded-pole motor.

      3. Discuss stator construction and poles for shaded-pole motors, using Information Sheet, Sections III and IV, and Transparency #1.

      4. Emphasize disadvantages of shaded-pole motors, using Information Sheet, Section V.

      5. Discuss voltages for and rotation reversal of shaded-pole motors, using Information Sheet, Sections VI and VII, and Transparency #2. Use an actual shaded-pole motor to demonstrate rotation reversal.

      6. Discuss methods of changing speed, using Information Sheet, Section VIII, and Transparency #3.

      7. Explain why replacement is the most common remedy for a defective shaded-pole motor, using Information Sheet, Section IX. Note that testing procedures are given in Job Sheet #1.

   F. Give test.

   G. Reteach and retest if necessary.

II. Instructional materials

   A. Objective sheet

SUGGESTED ACTIVITIES

B. Suggested activities

C. Information sheet

D. Transparency masters

    1. TM #1 — Stator Construction

    2. TM #2 — Electrical Reversal of Rotation

    3. TM #3 — Methods of Changing Motor Speed

E. Job Sheet #1 — Check a Shaded-Pole Motor

F. Test

G. Answers to test

III. Unit references

A. Althouse, Andrew D., Carl H. Turnquist, and Alfred F. Bracciano. *Modern Refrigeration and Air Conditioning*. Homewood, Illinois: Goodheart-Wilcox Co., 1975.

B. Schweitzer, Gerald. *Basics of Fractional Horsepower Motors and Repair*. Rochelle Park, New Jersey: Hayden Book Co., Inc., 1960.

SHADED-POLE MOTORS
UNIT II

INFORMATION SHEET

I. Terms and definitions

   A. Reactor coil — Coil of many turns of fine magnetic wire wired in series with stator of shaded-pole motor to provide a lower speed

      (NOTE: This coil is sometimes called a *choke*, and it looks much like a transformer.)

   B. Shading coil — Closed loop of wire placed in a slot in motor's stator pole; provides a phase shift to aid in motor starting and determines direction of rotation

II. Applications of shaded-pole motors

   A. Refrigerator evaporator fans

   B. Refrigerator condenser fans

   C. Window air-conditioner fans

   D. Furnace blowers

   E. Furnace combustion fans

   F. Timers

III. Stator construction of shaded-pole motors (Transparency #1)

   A. Poles are laminated

   B. Poles are slotted

   C. Stator winding is below shading slot

   D. Each shading coil is a closed loop

IV. Number of poles and their correct motor speeds

   (NOTE: Motor speed is determined by the number of poles.)

   A. Two poles — 3,600 rpm

   B. Four poles — 1,800 rpm

   C. Six poles — 1,200 rpm

INFORMATION SHEET

V. Disadvantages of shaded-pole motors

   A. Low torque

   B. Speed variation

   (NOTE: With a change in either load or applied voltage, the speed of a shaded-pole motor may vary over a wide range.)

   C. Inefficiency

VI. Voltages for shaded-pole motors

   (NOTE: Shaded-pole motors are not available in dual- or three-phase voltages.)

   A. 120-VAC single phase

   B. 240-VAC single phase

VII. Methods of reversing rotation of shaded-pole motors (Transparency #2)

   A. Mechanical

      1. Disassemble motor

      2. Reverse rotor assembly in stator

      3. Reassemble motor

   B. Electrical

   (NOTE: The following electrical characteristics have to be built into the motor at the time of manufacture.)

      1. With two sets of field coils per shading coil

         a. Use a double-pole double-throw switch

         b. Position switch to determine direction of rotation

      2. With two shaded-pole stators within one frame

         a. Use four motor leads

         b. Connect the set of leads needed for rotation desired

INFORMATION SHEET

VIII. Methods of changing speed in shaded-pole motors (Transparency #3)

A. Tapped stator winding

1. Increase speed by using portion of winding with least resistance

2. Lower speed by using complete winding for high resistance

B. Wired reactor coil in series with stator winding

1. Increase speed by shorting across reactor coil

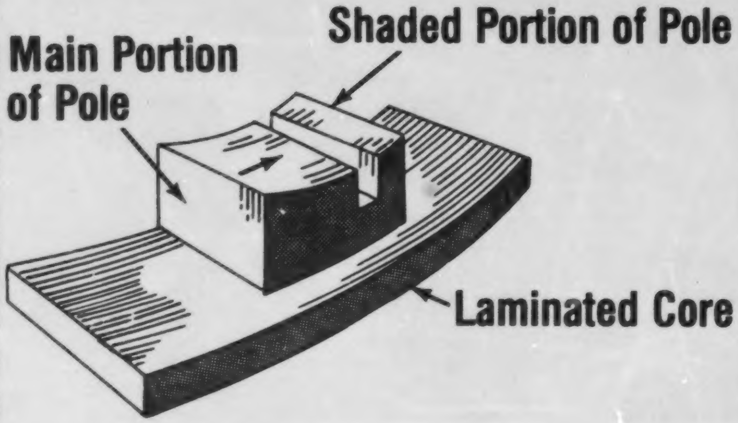
2. Lower speed by sending power through reactor coil

IX. Most common remedy for shaded-pole motor failure — Replacement

(NOTE: Shaded-pole motors are relatively inexpensive, and they are time-consuming to disassemble and repair. Therefore, replacement instead of major repair is generally the accepted remedy for motor failure.)

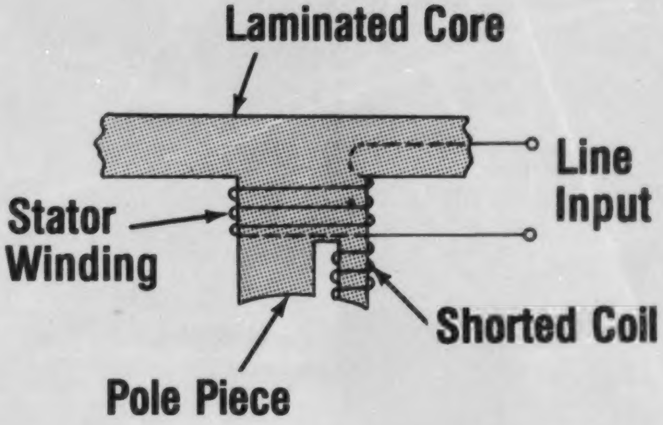
Stator Construction

Pole of a Shaded-Pole Motor


Shaded Portion of Pole
Main Portion of Pole
Laminated Core

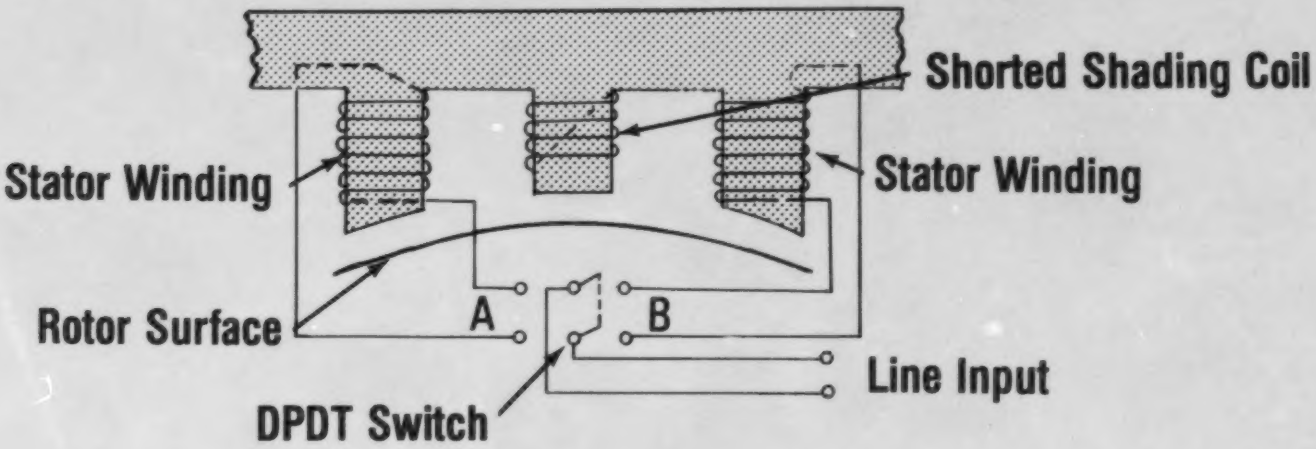
Arrow on main portion of pole indicates direction of rotor rotation.

Placement of Stator Windings on a Shaded-Pole Motor


Laminated Core
Line Input
Stator Winding
Shorted Coil
Pole Piece

Electrical Reversal of Rotation

One Pole of Laminated Core Cut into Three Subpoles

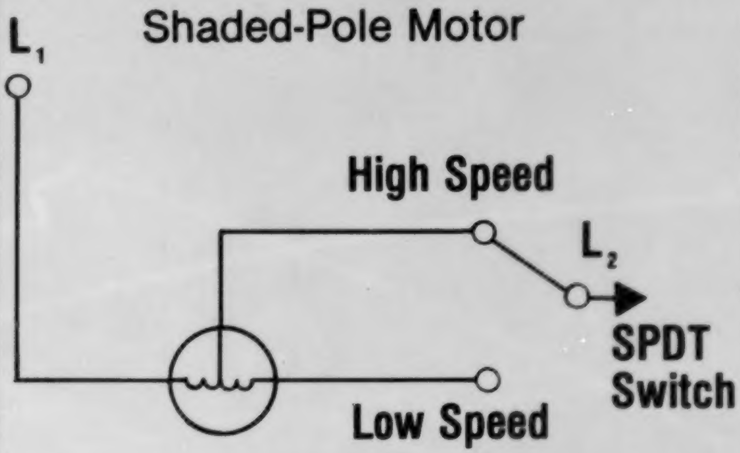

Shorted Shading Coil
Stator Winding
Stator Winding
A
B
Rotor Surface
Line Input
DPDT Switch

With switch at A, rotation is clockwise.
With switch at B, rotation is counterclockwise.

Methods of Changing Motor Speed

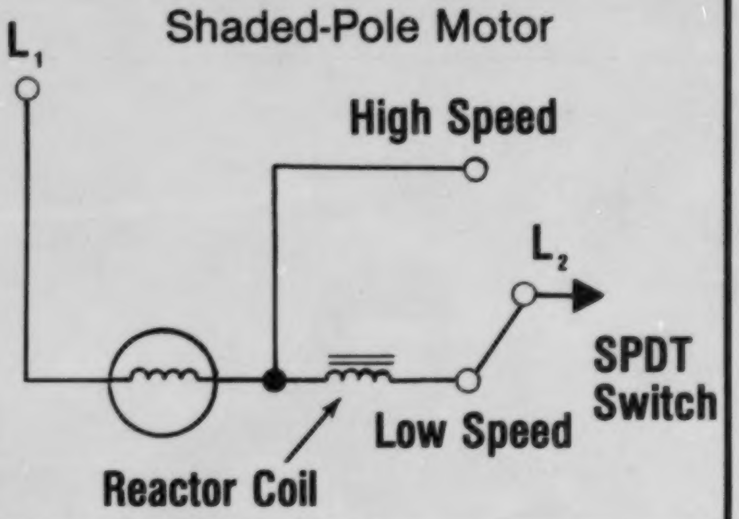
Tapped Winding

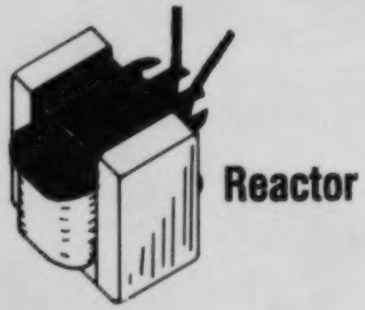
Shaded-Pole Motor


L_1
High Speed
L_2
SPDT
Switch
Low Speed

Reactor in Circuit

Shaded-Pole Motor


L_1
High Speed
L_2
SPDT
Switch
Low Speed
Reactor Coil



SHADED-POLE MOTORS
UNIT II

JOB SHEET #1 — CHECK A SHADED-POLE MOTOR

I. Equipment and materials

   A. Shaded-pole motor
   B. Power cord with test clips
   C. Ammeter or wattmeter
   D. Bench vise
   E. Compressed air
   F. Motor cleaning fluid
   G. Shop towel
   H. Eye protection
   I. Ohmmeter
   J. Polishing cloth

II. Procedure

   A. Put on eye protection
   B. Place motor in bench vise
   C. Clean motor with compressed air
   D. Clean outside of motor with cleaning fluid

      (NOTE: Clean motors run cooler and more efficiently.)

   E. Use ohmmeter to determine high and low speeds on stator-tapped motors
   F. Take hold of motor shaft and check side play and end play

      (NOTE: If side play or end play is excessive, have instructor check.)

   G. Connect test cord to motor leads
   H. Clamp ammeter around one motor lead, or connect wattmeter
   I. Plug in power cord

JOB SHEET #1

J. Check amperage reading

K. Disconnect power cord

L. Compare amperage reading to full-load amperage (FLA) on motor nameplate

(NOTE: Show work to instructor for evaluation and comments.)

M. Clean work area; return equipment and materials to their proper places

SHADED-POLE MOTORS
UNIT II

TEST

NAME ________________________________ SCORE ______________

1. Define terms associated with shaded-pole motors.

   a. Reactor coil — ____

   ____

   ____

   b. Shading coil — ____

   ____

   ____

2. Name five applications of shaded-pole motors.

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

3. Describe stator construction of shaded-pole motors.

   ____

   ____

   ____

   ____

4. Match number of poles to their correct motor speeds. Write the correct numbers in the blanks.

_____a.	1,800 rpm	1. Two poles
_____b.	3,600 rpm	2. Six poles
_____c.	1,200 rpm	3. Four poles

TEST

5. Name disadvantages of shaded-pole motors.

   a. ____

   b. ____

   c. ____

6. Name voltages for shaded-pole motors.

   a. ____

   b. ____

7. Describe methods of reversing rotation of shaded-pole motors.

   a. Mechanical — ________________________________

   b. Electrical — ________________________________

8. Describe methods of changing speed in shaded-pole motors.

   a. Tapped stator winding — ________________________

   b. Wired reactor coil in series with stator winding — ____________

TEST

9. State the most common remedy for shaded-pole motor failure.

____

(NOTE: Test question 10 lists the job sheet. It is an important part of this test. If it has not been completed, check with your instructor.)

10. Demonstrate the ability to check a shaded-pole motor.

SHADED-POLE MOTORS
UNIT II

ANSWERS TO TEST

1. a. Reactor coil — Coil of many turns of fine magnetic wire wired in series with stator of shaded-pole motor to provide a lower speed

   b. Shading coil — Closed loop of wire placed in a slot in the motor's stator pole; provides a phase shift to aid in motor starting and determines direction of rotation

2. Answer should include any five of the following

   a. Refrigerator evaporator fans

   b. Refrigerator condenser fans

   c. Window air-conditioner fans

   d. Furnace blowers

   e. Furnace combustion fans

   f. Timers

3. Description should include the following

   a. Poles are laminated

   b. Poles are slotted

   c. Stator winding is below shading slot

   d. Each shading coil is a closed loop

4. a. 3

   b. 1

   c. 2

5. a. Low torque

   b. Speed variation

   c. Inefficiency

ANSWERS TO TEST

6. a. 120-VAC single phase
   b. 240-VAC single phase

7. Description should include the following
   a. Mechanical
      1) Disassemble motor
      2) Reverse rotor assembly in stator
      3) Reassemble motor
   b. Electrical
      1) With two sets of field coils per shading coil
         a) Use a double-pole double-throw switch
         b) Position switch to determine direction of rotation
      2) With two shaded-pole stators within one frame
         a) Use four motor leads
         b) Connect the set of leads needed for rotation desired

8. Description should include the following
   a. Tapped stator winding
      1) Increase speed by using portion of winding with least resistance
      2) Lower speed by using complete winding for high resistance
   b. Wired reactor coil in series with stator winding
      1) Increase speed by shorting across reactor coil
      2) Lower speed by sending power through reactor coil

9. Replacement

10. Performance skills evaluated to the satisfaction of the instructor

SPLIT-PHASE MOTORS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to wire a split-phase dual-voltage motor to a 120-VAC or 208/240-VAC supply and disassemble, inspect, clean, and reassemble a split-phase motor. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with split-phase motors.
2. State the common horsepower range of split-phase motors.
3. List applications of split-phase motors.
4. List split-phase motor windings.
5. List characteristics of split-phase motor windings.
6. Discuss the purpose of the starting mechanism.
7. Label components of a split-phase motor.
8. Match start and run windings to National Electrical Manufacturers Association (NEMA) motor-lead numerical codes.
9. Match code numbers to National Electrical Manufacturers Association (NEMA) motor-lead color codes.
10. Identify directions of rotation.
11. Identify motor power wirings.
12. Demonstrate the ability to
    a. Disassemble, inspect, clean, check starting switch and centrifugal mechanism, and reassemble a split-phase motor.
    b. Wire a split-phase dual-voltage motor to a 208/240-VAC supply

SPLIT-PHASE MOTORS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives. State need for knowledge in each area.

  D. Provide students with information and job sheets.

  E. Discuss information and job sheets.

    1. Discuss terms and definitions, using Information Sheet, Section I, and Transparency #1. Use disassembled motor to relate terms to parts of the motor.

    2. Use Information Sheet, Sections II and III, to discuss horsepower range and applications for split-phase motors. Split-phase motors are designed for small jobs and operate on fractional horsepower.

    3. Use Information Sheet, Sections IV and V, and Transparency #2 to discuss windings and their characteristics for split-phase motors.

    4. Use Information Sheet, Sections VI and VII, and Transparency #3 to discuss purpose for and components of start and run mechanisms. Show parts of start mechanism on motor.

    5. Use Information Sheet, Sections VIII and IX, and Transparency #4 to discuss motor leads and their numerical and color codes. Use actual motor to show lead color codes for start and run.

    6. Use Information Sheet, Sections X and XI, and Transparencies #5 through #7 to discuss rotation and power wiring. Use motor to demonstrate procedure. Job Sheets #1 and #2 will help the student understand the construction and wiring methods for split-phase motors.

  F. Give test.

  G. Reteach and retest if necessary.

II. Instructional materials

  A. Objective sheet

SUGGESTED ACTIVITIES

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Split-Phase Motors
2. TM #2 — Characteristics of Start and Run Windings
3. TM #3 — Components of a Split-Phase Motor
4. TM #4 — NEMA Motor-Lead Color Code
5. TM #5 — Motor Wiring for Rotations
6. TM #6 — Motor Wiring for a 120-VAC Operation
7. TM #7 — Motor Wiring for a 208/240-VAC Operation

E. Job sheets

1. Job Sheet #1 — Disassemble, Inspect, Clean, Check Starting Switch and Centrifugal Mechanism, and Reassemble a Split-Phase Motor
2. Job Sheet #2 — Wire a Split-Phase Dual-Voltage Motor to a 208/240-VAC Supply

F. Test

G. Answers to test

III. Unit references

A. Althouse, Andrew D., Carl H. Turnquist, and Alfred F. Bracciano. *Modern Refrigeration and Air Conditioning*. Homewood, Illinois: Goodheart-Willcox Company, 1975.

B. Schweitzer, Gerald. *Basics of Fractional Horsepower Motors and Repair*. Rochelle Park, New Jersey: Hayden Book Company, Inc., 1960.

C. Wantiez, Gary W. *Air Conditioning and Refrigeration, Book Two*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

SPLIT-PHASE MOTORS
UNIT III

INFORMATION SHEET

I. Terms and definitions

   A. Torque — Force that produces a rotating or twisting action

   B. Start winding — Winding in electric motor used only while motor is starting

   C. Run winding — Winding in electric motor that has current flowing through it constantly during normal operation

   D. Split-phase motor — Motor with two stator windings; both windings are in use for starting; the start winding is disconnected by centrifugal switch after motor attains approximately 75 to 80 percent of its normal speed; motor then operates on run winding only (Transparency #1)

II. Common horsepower range of split-phase motors — 1/20 to 3/4 horsepower

III. Applications of split-phase motors

   A. Fans

   B. Oil burners

   C. Pumps

   D. Blowers

   E. Domestic refrigerator compressors

IV. Split-phase motor windings

   A. Start

   B. Run

V. Characteristics of split-phase motor windings (Transparency #2)

   A. Start winding

      1. Has high resistance

      2. Is made of light wire

      3. Is composed of many turns

      4. Is wound near top of pole slots

INFORMATION SHEET

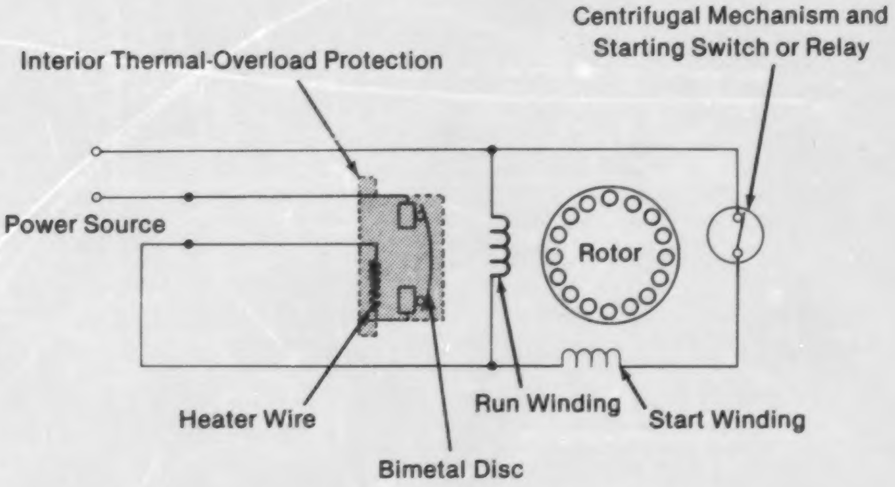
B. Run winding

1. Has low resistance
2. Is made of heavy wire
3. Is composed of few turns
4. Is wound near bottom of pole slots

VI. Purpose of the starting mechanism — Opens starting switch to remove start winding when motor reaches approximately 75 to 80 percent of its normal speed

VII. Components of a split-phase motor (Figure 1; Transparency #3)

FIGURE 1


Centrifugal Mechanism and Starting Switch or Relay
Interior Thermal-Overload Protection
Power Source
Rotor
Heater Wire
Run Winding
Start Winding
Bimetal Disc

VIII. NEMA motor-lead numerical codes for start and run windings

(NOTE: No standard numbers have been developed for terminal markings of multispeed motors.)

A. Single voltage (Figure 2)

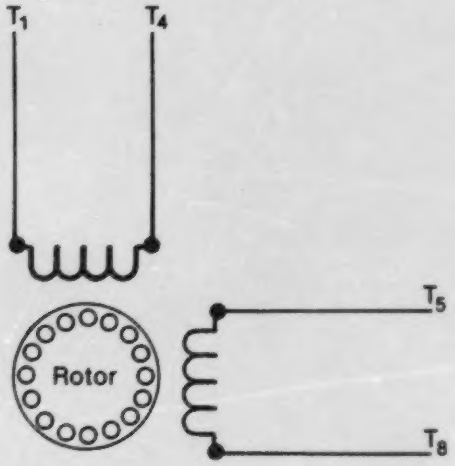
(NOTE: Odd-to-odd-numbered terminals of each winding are joined for low voltage [parallel connection], and odd-to-even-numbered terminals of each winding are joined for higher voltage [series connection].)

INFORMATION SHEET

1. Start winding — T5 and T8
2. Run winding — T1 and T4

EXAMPLE:

FIGURE 2


T_1
T_4
T_5
T_8
Rotor

Single Voltage

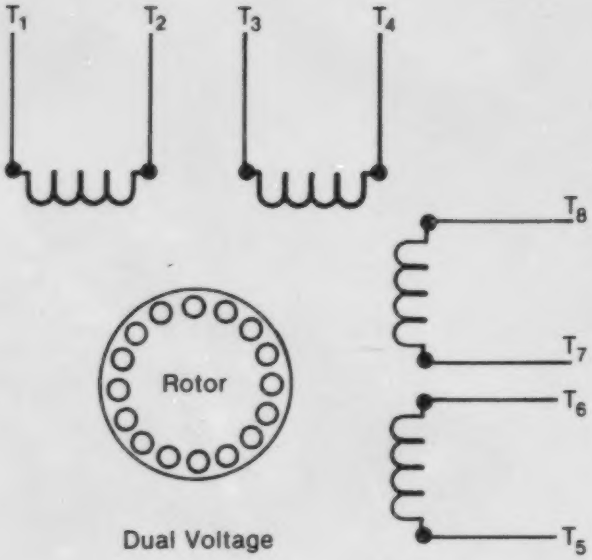
INFORMATION SHEET

B. Dual voltage (Figure 3)

1. Start winding — T5, T6, T7, and T8
2. Run winding — T1, T2, T3, and T4

EXAMPLE:

FIGURE 3



Dual Voltage

IX. NEMA motor-lead color codes (Transparency #4)

(NOTE: No standard colors have been assigned to multispeed motors or to P1 motor leads.)

A. T1 — Blue

B. T2 — White

C. T3 — Orange

D. T4 — Yellow

E. T5 — Black

F. T8 — Red

G. P2 — Brown

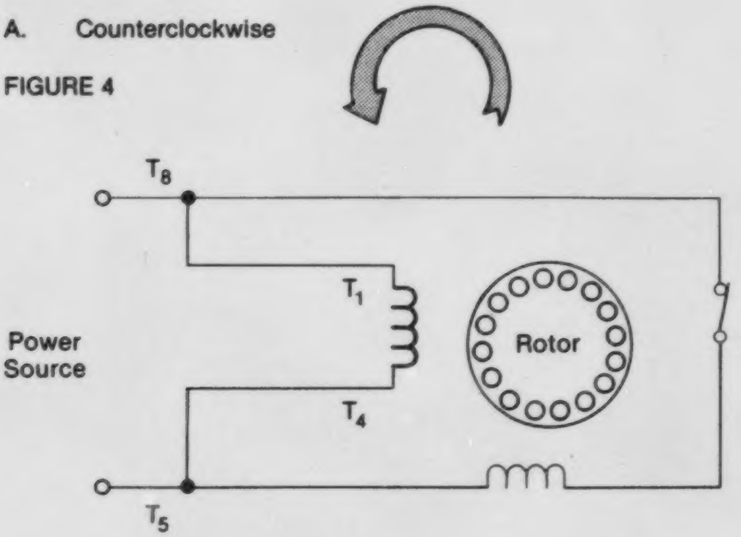
INFORMATION SHEET

X. Directions of rotation (Figures 4 and 5; Transparency #5)

(NOTE: The directions of rotation in Figures 4 and 5 were determined by facing back end of motor.)

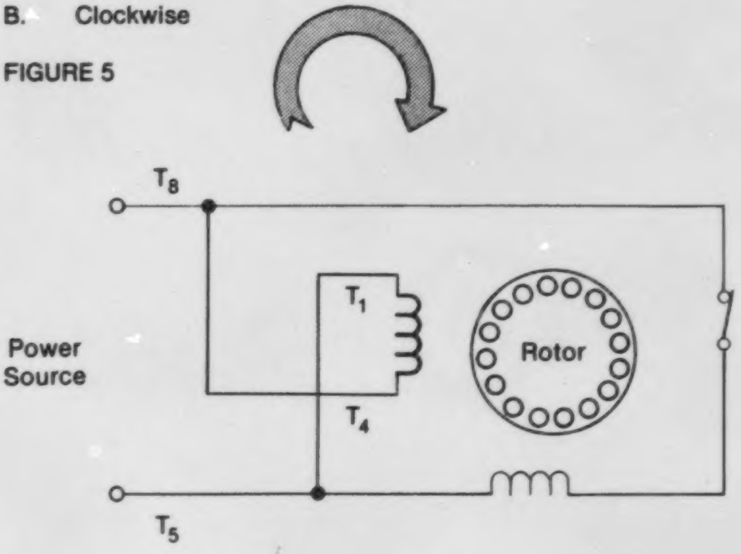
A. Counterclockwise

FIGURE 4


T8
T1
Rotor
Power Source
T4
T5

B. Clockwise

FIGURE 5

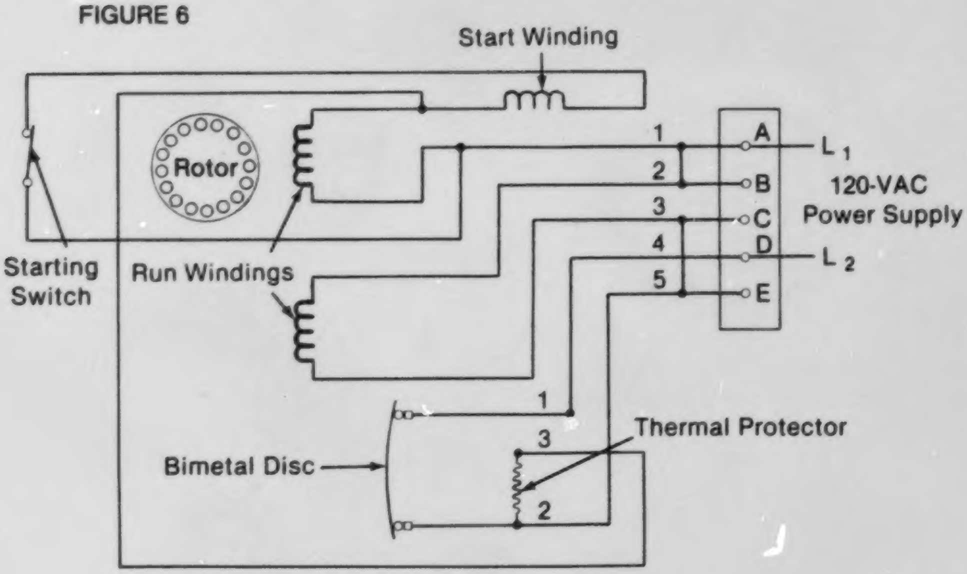

T8
T1
Rotor
Power Source
T4
T5

INFORMATION SHEET

XI. Motor power wirings (Figures 6 and 7; Transparencies #6 and #7)

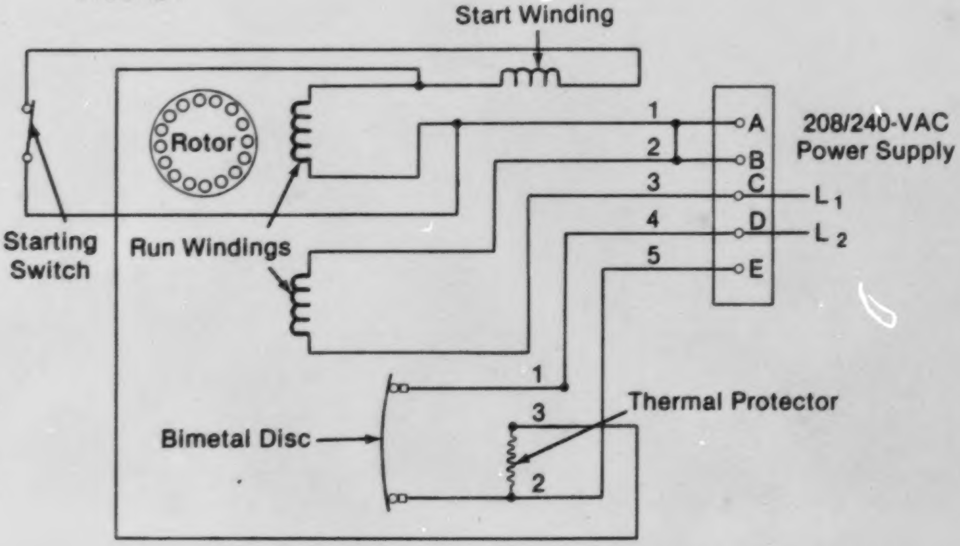
A. 120-VAC operation

FIGURE 6

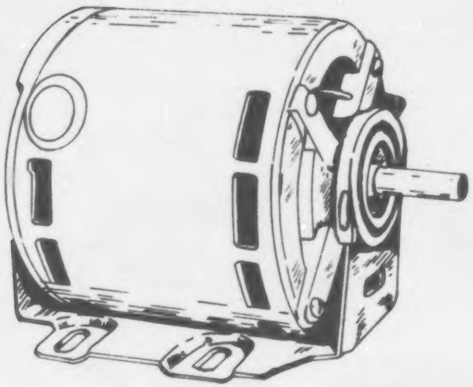

Start Winding
Rotor
1
2
3
4
5
A
B
C
D
E
L 1
L 2
120-VAC
Power Supply
Starting Switch
Run Windings
1
3
2
Thermal Protector
Bimetal Disc

B. 208/240-VAC operation

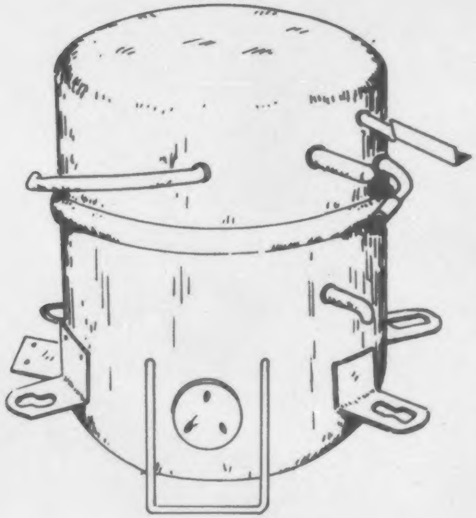
FIGURE 7


Start Winding
Rotor
1
2
3
4
5
A
B
C
D
E
208/240-VAC
Power Supply
L 1
L 2
Starting Switch
Run Windings
1
3
2
Thermal Protector
Bimetal Disc

Split-Phase Motors

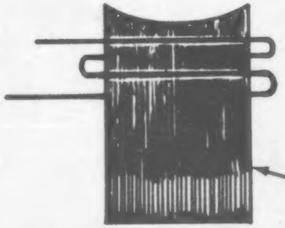
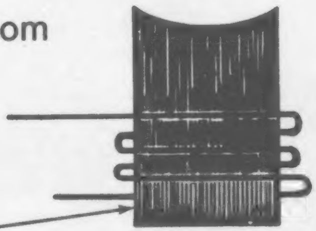


Open-Drive Motor

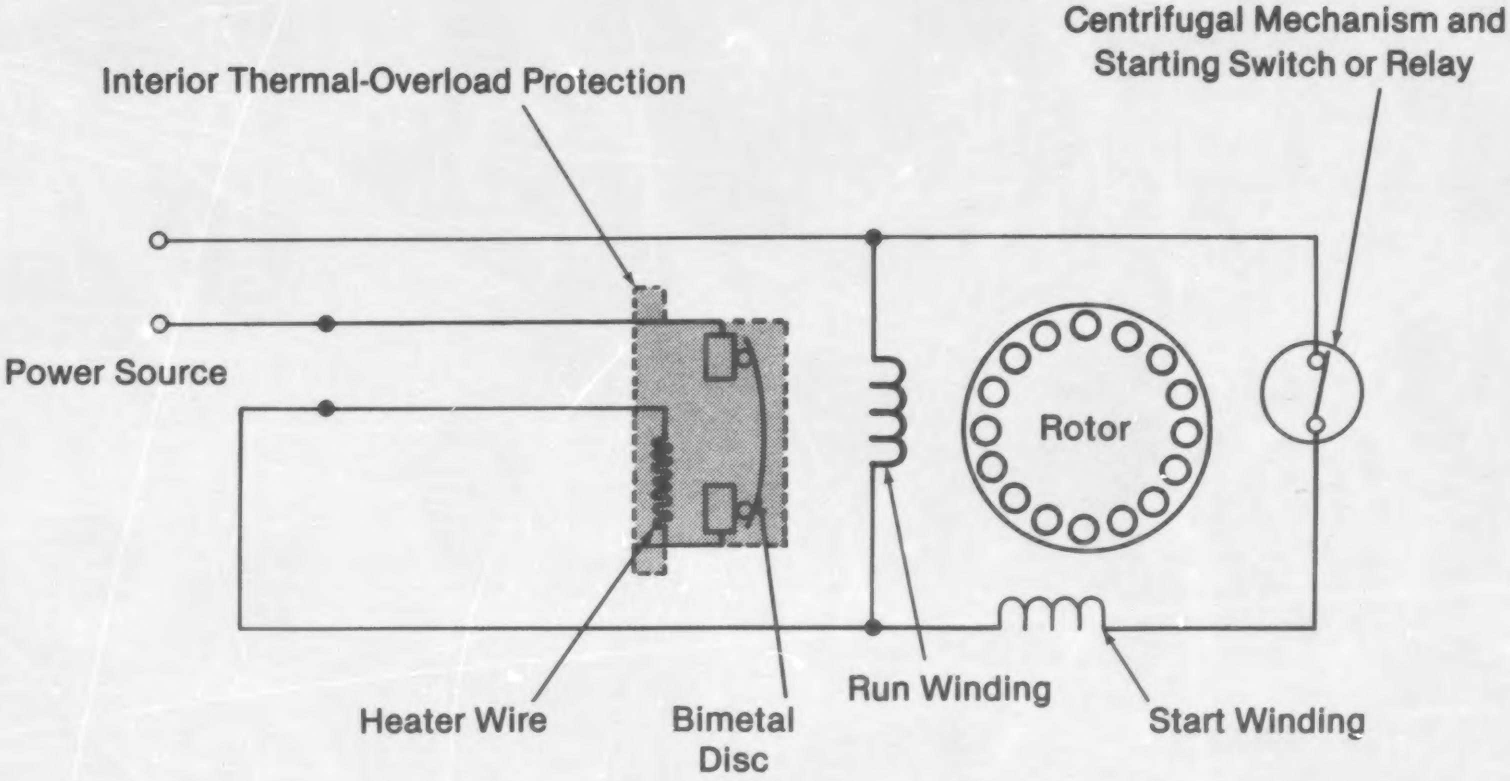


Hermetic Motor

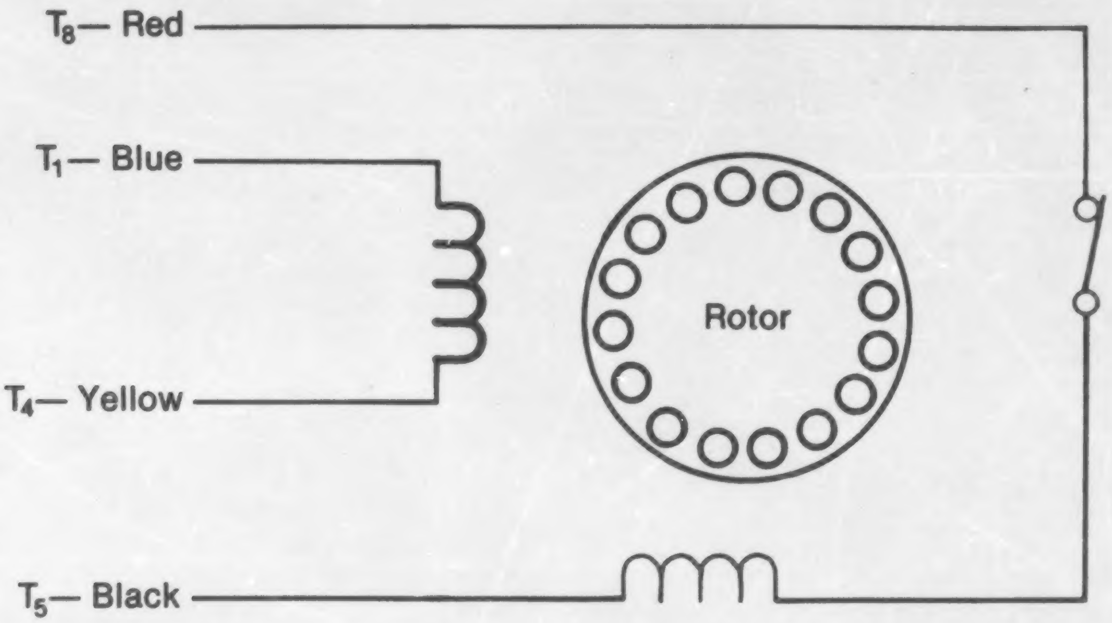
Characteristics of Start and Run Windings

Start	Run
High Resistance	Low Resistance
Light Wire	Heavy Wire
Many Turns	Few Turns
Wound Near Top of Pole Slots 	Wound Near Bottom of Pole Slots 

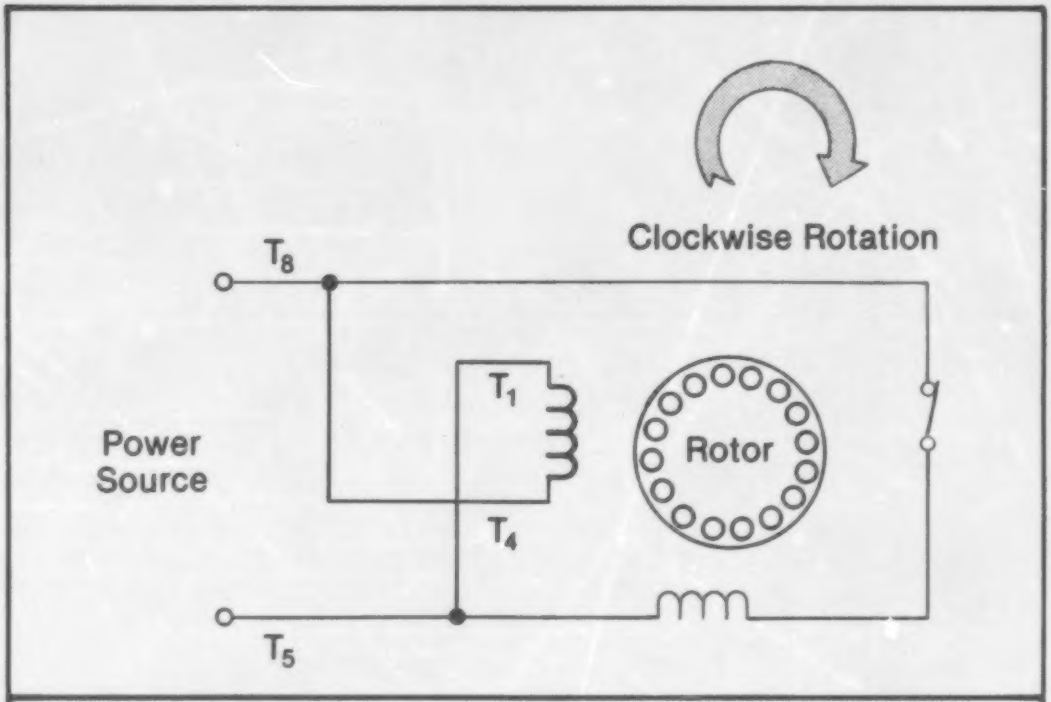
Components of a Split-Phase Motor

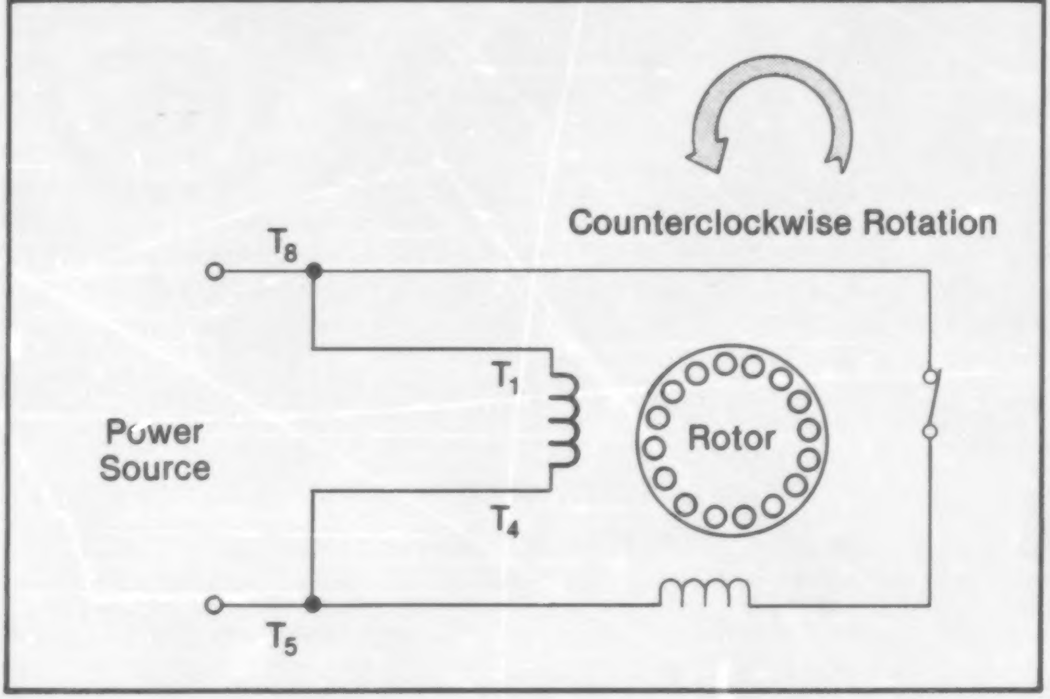

Centrifugal Mechanism and Starting Switch or Relay
Interior Thermal-Overload Protection
Power Source
Rotor
Heater Wire
Bimetal Disc
Run Winding
Start Winding

NEMA Motor-Lead Color Code

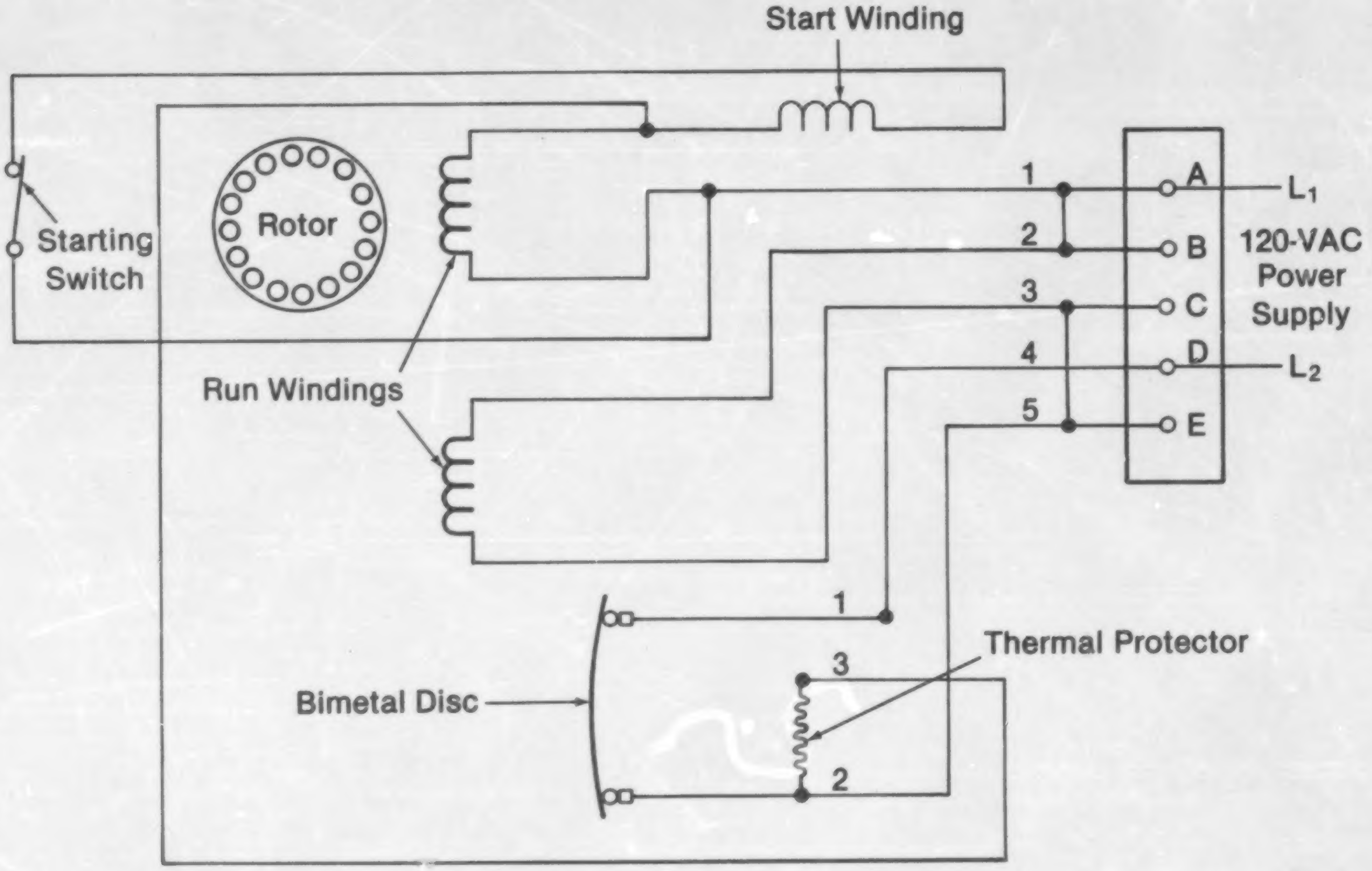

T_8— Red
T_1— Blue
T_4— Yellow
T_5— Black
Rotor

Motor Wiring for Rotations

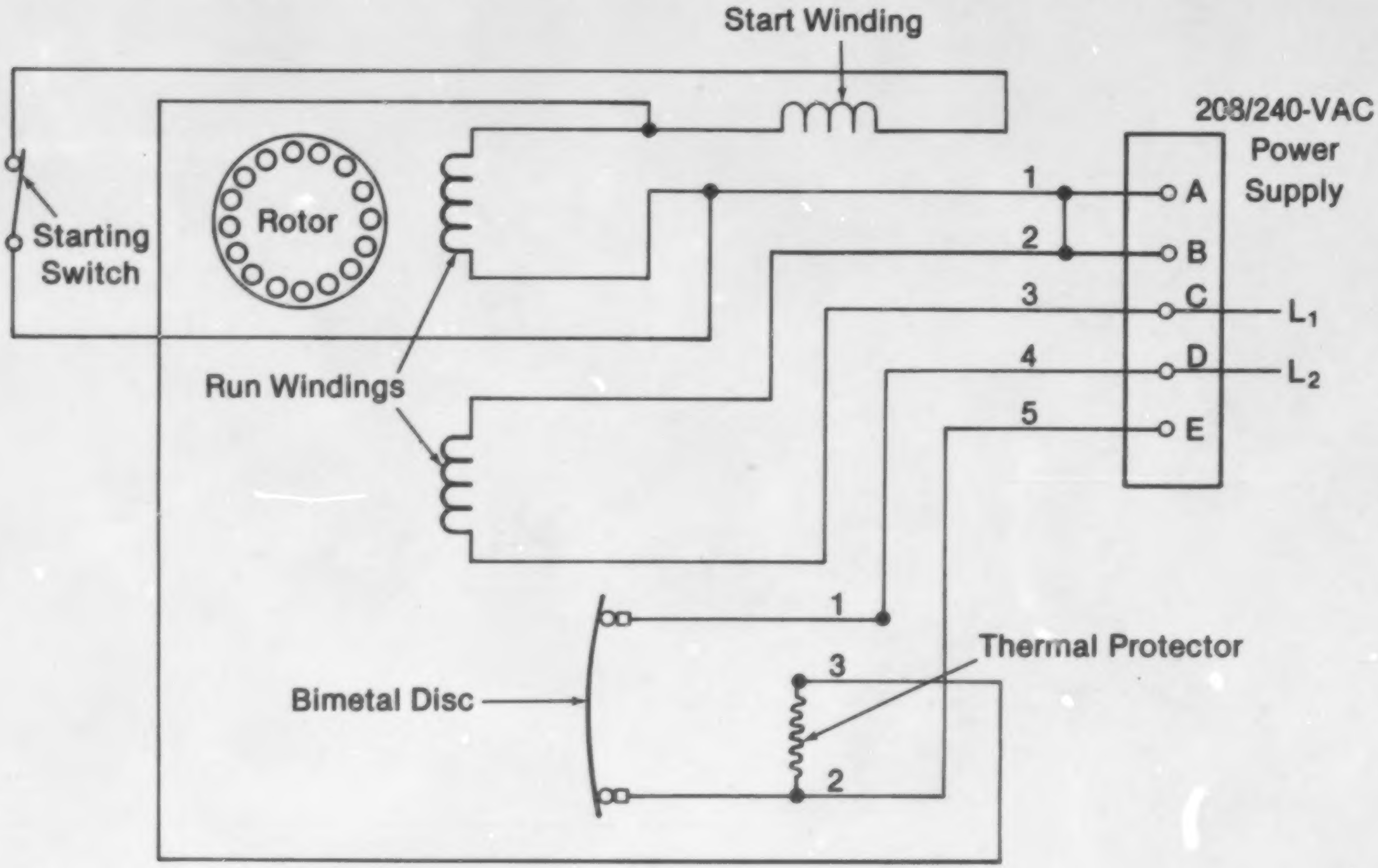

Clockwise Rotation
T_8
T_1
Power Source
Rotor
T_4
T_5


Counterclockwise Rotation
T_8
T_1
Power Source
Rotor
T_4
T_5

Motor Wiring for a 120-VAC Operation


Start Winding
Starting Switch
Rotor
Run Windings
1
2
3
4
5
A
B
C
D
E
L₁
L₂
120-VAC Power Supply
1
3
2
Bimetal Disc
Thermal Protector

Motor Wiring for a 208/240-VAC Operation


Start Winding
208/240-VAC
Power
Supply
Starting
Switch
Rotor
Run Windings
1
2
3
4
5
A
B
C
D
E
L1
L2
1
3
2
Thermal Protector
Bimetal Disc

TM #7

IE - 123-B

SPLIT-PHASE MOTORS
UNIT III

JOB SHEET #1 — DISASSEMBLE, INSPECT, CLEAN, CHECK STARTING SWITCH AND CENTRIFUGAL MECHANISM, AND REASSEMBLE A SPLIT-PHASE MOTOR

I. Equipment and materials

- A. Split-phase motor
- B. Screwdriver set
- C. Combination wrench set
- D. Center punch
- E. Ball peen hammer
- F. Soft-faced hammer
- G. Small socket wrench set
- H. Motor cleaning fluid
- I. Clean shop towel
- J. Compressed air
- K. Eye protection
- L. Lead marking material
- M. Polishing cloth
- N. Gear puller
- O. Machine oil

II. Procedure

- A. Put on eye protection
- B. Check to be sure that electrical power is disconnected and locked open
- C. Remove motor from equipment, if necessary, and mark leads
- D. Clean outer surface of motor
- E. Disconnect wires at motor terminals

  (NOTE: Label wire positions by number or color on motor terminals, or draw a diagram.)

JOB SHEET #1

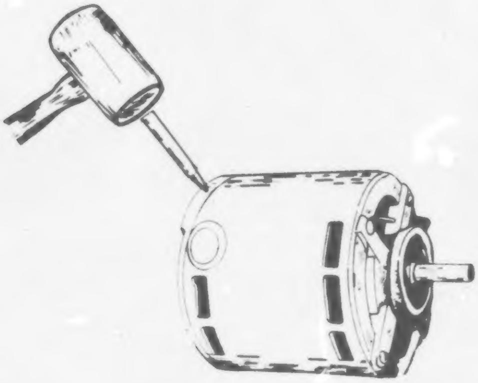
F. Remove motor pulley

G. Mark end bells to keep them in their proper places (Figure 8)

1. Using center punch, place one mark on pulley end bell and two marks on opposite end bell

2. Mark housing in the same way

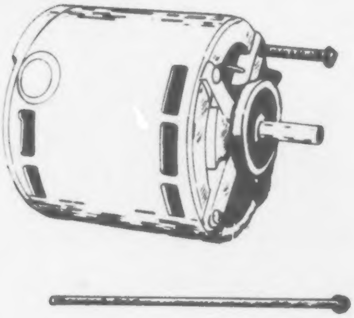
FIGURE 8



H. Check motor for end play

I. Remove bolts holding end bells (Figure 9)

FIGURE 9

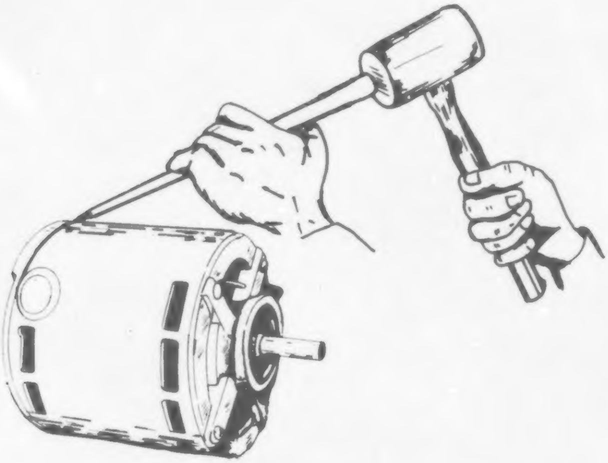


JOB SHEET #1

J. Polish shaft ends for easy removal

K. Use soft-faced hammer and punch to tap end bells loose (Figure 10)

FIGURE 10



L. Remove end bell that does not contain starting switch

M. Remove rotor

(NOTE: Observe position and number of thrust washers as you remove the rotor.)

N. Remove end bell containing starting switch

(CAUTION: Do not attempt to remove stator.)

O. Clean motor with compressed air

P. Check centrifugal mechanism and starting switch

Q. Clean outside of motor with special cleaning fluid

R. Check stator coils, insulation, and coil supports

S. Clean bearings, and make sure that wicking is in place and oiled

(CAUTION: Do not clean ball bearings with compressed air.)

T. Reinstall end bell containing starting switch

JOB SHEET #1

U. Insert rotor, making sure that thrust washers are in place

(NOTE: Place a drop of oil on bearing part of the shaft.)

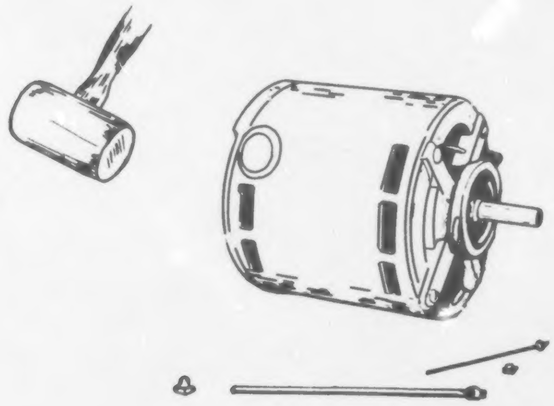
V. Reinstall second end bell

W. Visually inspect rotor and stator alignment

X. Check position of end bells to center punch marks

Y. Use soft-faced hammer to tap end bells into place (Figure 11)

FIGURE 11



Z. Insert end-bell bolts; tighten

AA. Turn shaft by hand, and check for end play

(NOTE: If shaft is tight, end bells may not be in proper alignment, or the wicking may be between bearing and shaft.)

BB. Connect temporary leads; test motor

(NOTE: Show work to instructor for evaluation and comments.)

CC. Clean work area; put equipment and materials in proper storage

SPLIT-PHASE MOTORS
UNIT III

JOB SHEET #2 — WIRE A SPLIT-PHASE DUAL-VOLTAGE MOTOR TO A 208/240-VAC SUPPLY

I. Equipment and materials

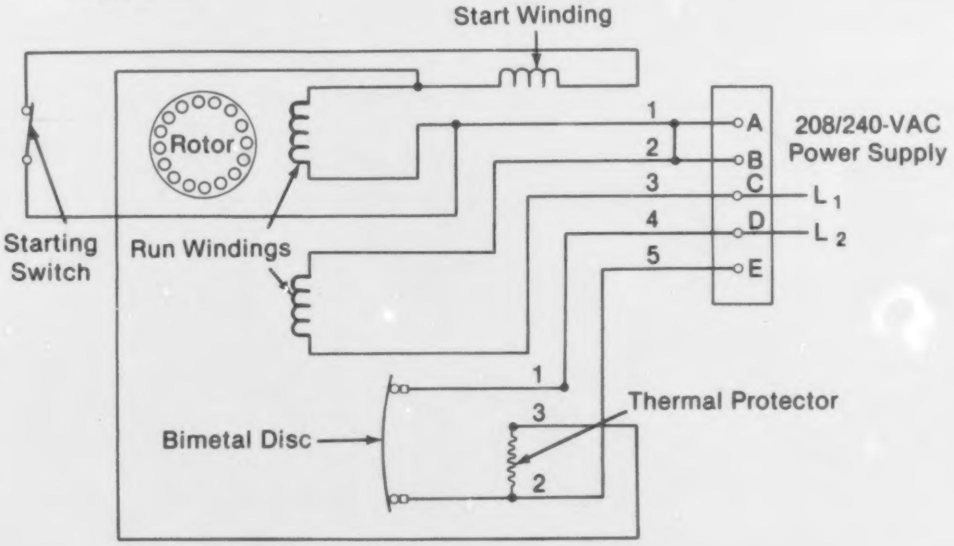
A. Ammeter

B. Voltmeter

C. Dual-voltage split-phase motor

II. Procedure for 208/240-volt connection

FIGURE 12


Start Winding
Rotor
1
2
3
4
5
A
B
C
D
E
208/240-VAC Power Supply
L 1
L 2
Starting Switch
Run Windings
1
3
2
Thermal Protector
Bimetal Disc

A. Check to be sure that all electrical power is disconnected and locked open

B. Connect lead 3 to L1 (Figure 12)

C. Connect leads 1 and 2 to each other

D. Connect lead 4 to L2

(NOTE: Have instructor inspect wiring.)

E. Place voltmeter at 250-VAC or higher range

JOB SHEET #2

F. Clip voltmeter leads to motor leads 3 and 4

G. Place ammeter in highest range

H. Clamp ammeter around L1 or L2

I. Turn on electrical power to start motor

J. Adjust ammeter for most accurate reading

K. Record readings

Volts = ____________________

Amps = ____________________

L. Disconnect power supply to motor, and lock open

(NOTE: Show work to instructor for evaluation and comments.)

M. Clean work area; put equipment and materials in proper storage

SPLIT-PHASE MOTORS
UNIT III

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct definitions terms associated with split-phase motors. Write the correct numbers in the blanks.

_____a. Force that produces a rotating or twisting action

_____b. Winding in electric motor that has current flowing through it constantly during normal operation

_____c. Motor with two stator windings; both windings are in use for starting; the start winding is disconnected by centrifugal switch after motor attains approximately 75 to 80 percent of its normal speed; motor then operates on run winding only

_____d. Winding in electric motor used only while motor is starting

1. Split-phase motor
2. Start winding
3. Run winding
4. Torque

2. State the common horsepower range of split-phase motors.

____

3. List four applications of split-phase motors.

a. ____

b. ____

c. ____

d. ____

4. List split-phase motor windings.

a. ____

b. ____

TEST

5. List characteristics of split-phase motor windings.

   a. Start winding

      1) ______________________________

      2) ______________________________

      3) ______________________________

      4) ______________________________

   b. Run winding

      1) ______________________________

      2) ______________________________

      3) ______________________________

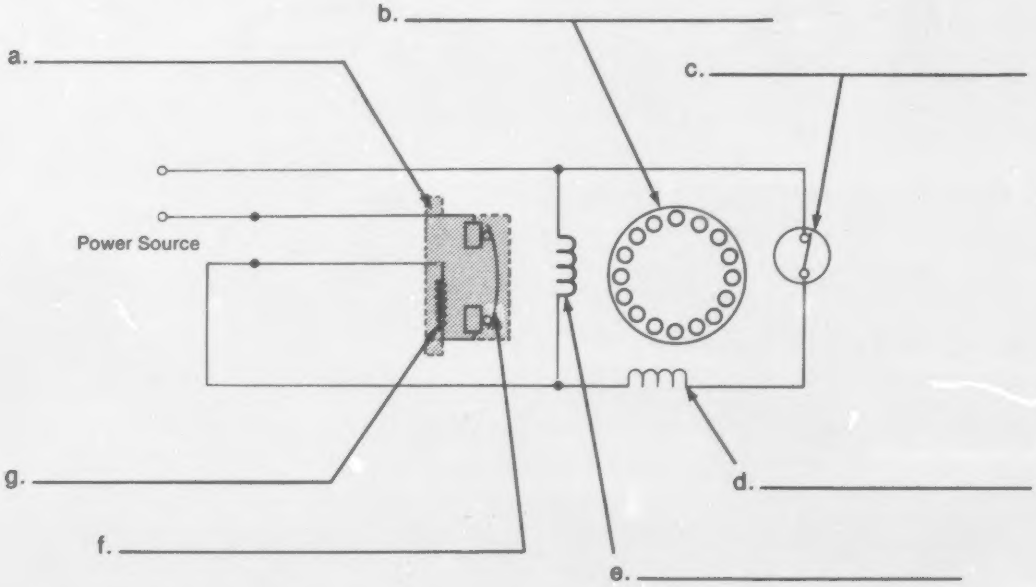
      4) ______________________________

6. Discuss the purpose of the starting mechanism.

   ____

   ____

7. Label components of a split-phase motor. Write the correct names in the blanks.



TEST

8. Match start and run windings to National Electrical Manufacturers Association (NEMA) motor-lead numerical codes. Write the correct numbers in the blanks. Answers may be used more than once.

Single voltage

_____a. T4
_____b. T5
_____c. T1
_____d. T8

1. Start winding
2. Run winding

Dual voltage

_____a. T4
_____b. T8
_____c. T5
_____d. T2
_____e. T7
_____f. T1
_____g. T6
_____h. T3

9. Match code numbers to National Electrical Manufacturers Association (NEMA) motor-lead color codes. Write the correct numbers in the blanks.

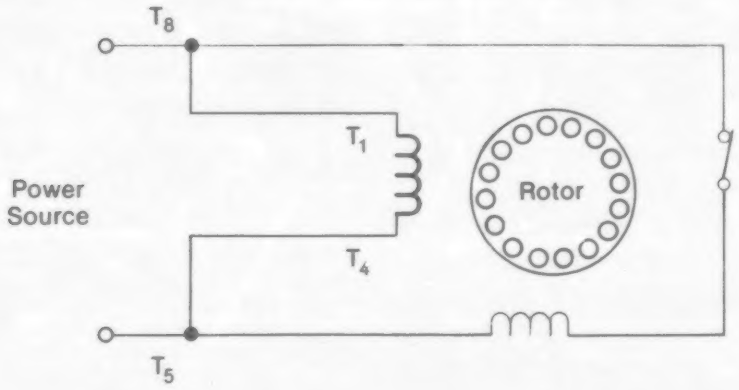
_____a. Yellow
_____b. White
_____c. Red
_____d. Orange
_____e. Black
_____f. Blue
_____g. Brown

1. T3
2. T4
3. T2
4. T5
5. T1
6. T8
7. P2

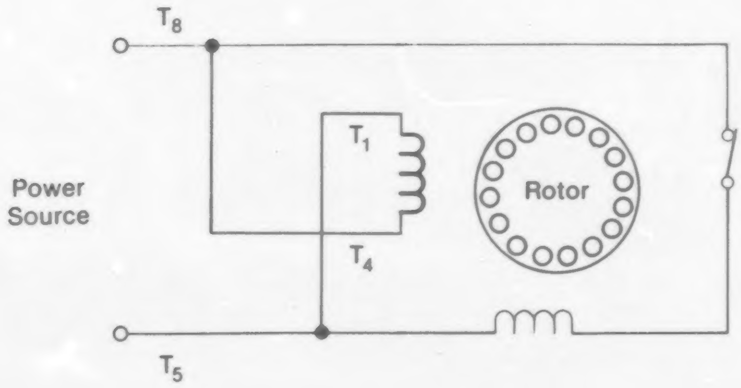
TEST

10. Identify directions of rotation. Write the correct direction of rotation in the blanks.

Clockwise **Counterclockwise**


T8
T1
Power
Source
Rotor
T4
T5

a. ______________________________

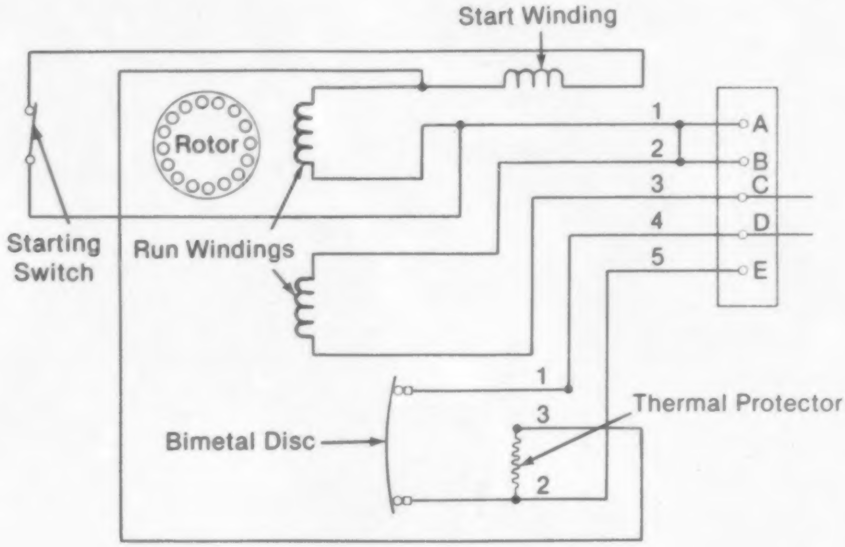

T8
T1
Power
Source
Rotor
T4
T5

b. ______________________________

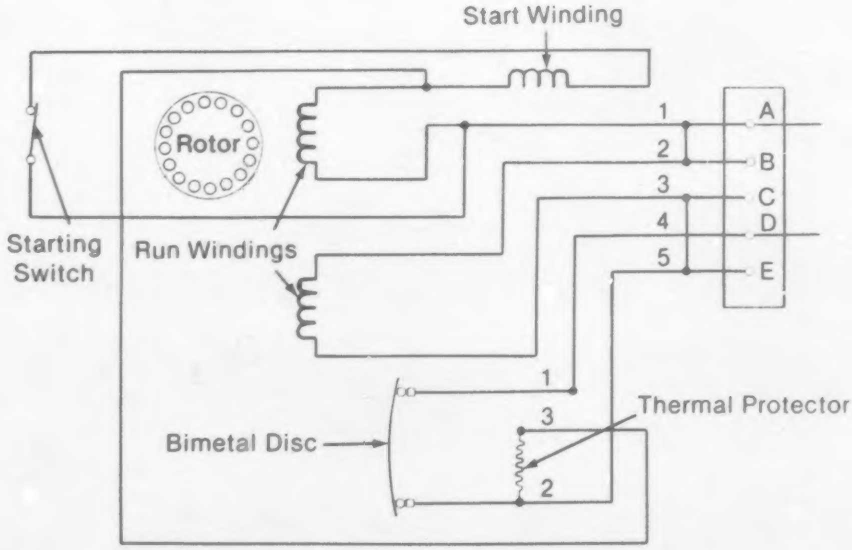
TEST

11. Identify motor power wirings. Write the correct names in the blanks.

120-VAC operation **208/240-VAC operation**


Start Winding
Rotor
Starting Switch
Run Windings
1
2
3
4
5
A
B
C
D
E
1
3
2
Bimetal Disc
Thermal Protector

a. ______________________________


Start Winding
Rotor
Starting Switch
Run Windings
1
2
3
4
5
A
B
C
D
E
1
3
2
Bimetal Disc
Thermal Protector

b. ______________________________

TEST

(NOTE: Test question 12 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

12. Demonstrate the ability to

    a. Disassemble, inspect, clean, check starting switch and centrifugal mechanism, and reassemble a split-phase motor.

    b. Wire a split-phase dual-voltage motor to a 208/240-VAC supply.

SPLIT-PHASE MOTORS
UNIT III

ANSWERS TO TEST

1. a. 4
   b. 3
   c. 1
   d. 2

2. $^{1}/_{20}$ to $^{3}/_{4}$ horsepower

3. Answer should include any four of the following
   a. Fans
   b. Oil burners
   c. Pumps
   d. Blowers
   e. Domestic refrigerator compressors

4. a. Start
   b. Run

5. a. Start winding
      1) Has high resistance
      2) Is made of light wire
      3) Is composed of many turns
      4) Is wound near top of pole slots

   b. Run winding
      1) Has low resistance
      2) Is made of heavy wire

ANSWERS TO TEST

3) Is composed of few turns

4) Is wound near bottom of pole slots

6. Discussion should include the following

Opens starting switch to remove start winding when motor reaches approximately 75 to 80 percent of its normal speed

7. a. Interior thermal-overload protection

b. Rotor

c. Centrifugal mechanism and starting switch or relay

d. Start winding

e. Run winding

f. Bimetal disc

g. Heater wire

8. **Single voltage**

a. 2

b. 1

c. 2

d. 1

Dual voltage

a. 2

b. 1

c. 1

d. 2

e. 1

f. 2

g. 1

h. 2

ANSWERS TO TEST

9. a. 2
   b. 3
   c. 6
   d. 1
   e. 4
   f. 5
   g. 7

10. a. Counterclockwise
    b. Clockwise

11. a. 208/240-VAC operation
    b. 120-VAC operation

12. Performance skills evaluated to the satisfaction of the instructor

CAPACITOR MOTORS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to complete wiring diagrams for and test capacitor-start induction-run, capacitor-start capacitor-run, and permanent split capacitor motors. The student will show this knowledge by completing assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with capacitor motors to their correct definitions.
2. Name types of capacitor motors.
3. Describe characteristics of capacitor motors.
4. Describe capacitor-start induction-run (CSIR) motors.
5. Describe capacitor-start capacitor-run (CSR) motors.
6. Describe permanent split capacitor (PSC) motors.
7. Identify the wiring diagrams of CSIR, CSR, and PSC motors.
8. Complete wiring diagrams for capacitor motors.
9. Demonstrate the ability to
    a. Test capacitors with an ohmmeter.
    b. Reverse a capacitor motor.
    c. Identify run, common, and start terminals on a hermetically sealed compressor unit.
    d. Test current relay.
    e. Test potential relay.

CAPACITOR MOTORS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

  A. Make transparencies.

  B. Provide students with objective sheet.

  C. Discuss unit and specific objectives. Tell how each objective applies to servicing and installing capacitor motors.

  D. Provide students with information, assignment, and job sheets.

  E. Discuss information, assignment, and job sheets.

    1. Discuss terms and definitions, using Information Sheet, Section I. Use a motor and capacitor for visual identification of new terms.

    2. Discuss the types of capacitor motors, using Information Sheet, Section II.

    3. Discuss the characteristics of capacitor motors, using Information Sheet, Section III. Refer to "Split-Phase Motors," Unit III, Section B, and compare the characteristics of split-phase motors with those of capacitor motors.

    4. Discuss CSIR motors, using information Sheet, Section IV and Transparency #1. Use Assignment Sheet #1 to reinforce knowledge of CSIR wiring methods.

    5. Discuss CSR motors using Information Sheet, Section V and Transparency #2. Use Assignment Sheet #1 to reinforce knowledge of CSR wiring methods.

    6. Discuss PSC motors, using Information Sheet, Section VI and Transparency #3. Use Assignment Sheet #1 to reinforce knowledge of PSC wiring methods.

    7. Discuss wiring diagrams by viewing Transparencies #1-#3. Point out the main differences in CSIR, CSR, and PSC motors.

    8. Demonstrate the proper procedure for testing a capacitor, using Job Sheet #1.

    9. Demonstrate the proper method for reversing a capacitor, using Job Sheet #2.

    10. Demonstrate the procedure for identifying the leads on a sealed capacitor motor, using Job Sheet #3.

  F. Give test.

SUGGESTED ACTIVITIES

II. Instructional materials

- A. Objective sheet
- B. Suggested activities
- C. Information sheet
- D. Transparency masters
    - 1. TM #1 — CSIR Motor Wiring
    - 2. TM #2 — CSR Motor Wiring
    - 3. TM #3 — PSC Motor Wiring
- E. Assignment Sheet #1 — Complete Wiring Diagrams for Capacitor Motors
- F. Answers to assignment sheet
- G. Job sheets
    - 1. Job Sheet #1 — Test Capacitors with an Ohmmeter
    - 2. Job Sheet #2 — Reverse a Capacitor Motor
    - 3. Job Sheet #3 — Identify Run, Common, and Start Terminals on a Hermetically Sealed Compressor Unit
    - 4. Job Sheet #4 — Test Current Relay
    - 5. Job Sheet #5 — Test Potential Relay
- H. Test
- I. Answers to test

III. Unit references

- A. Althouse, Andrew E., Carl H. Turnquist, and Alfred E. Bracciano. *Modern Refrigeration and Air Conditioning*. Homewood, Illinois: Goodheart-Willcox Co., 1975.
- B. Grim, John H. *Refrigeration System Components*. Sidney, Ohio: Compeland Refrigeration Corp., 1967.
- C. Schweitzer, Gerald. *Basics of Fractional Horsepower Motors and Repair*. Rochelle Park, New Jersey: Hayden Book Co., Inc., 1960.
- D. Wantiez, Gary W. *Air Conditioning and Refrigeration, Book Two*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

CAPACITOR MOTORS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

   A. Dual-voltage motor — Motor designed to operate on two voltages

   B. Capacitor motor — Motor that uses a start capacitor and/or a run capacitor in the electrical circuit

   C. Hermetic motor — Motor that is sealed in the airtight dome with the compressor

   D. Potential relay — Magnet relay installed in parallel with load; operates due to voltage applied to coil

   E. Current relay — Magnet relay installed in series with load; operates when current reaches a predetermined value, or drops out when current drops too low

   F. Thermal relay — Relay that operates due to temperature changes

   G. Bleeder resistor — High resistance resistor attached between capacitor terminals to drain off the electrical charge

II. Types of capacitor motors

   A. Capacitor-start induction-run (CSIR)

   B. Capacitor-start capacitor-run (CSR)

   C. Permanent split capacitor (PSC)

III. Characteristics of capacitor motors

   A. Are essentially the same design as split-phase motors but parts are not interchangeable

   (NOTE: Never attempt to increase the torque of a split-phase motor by inserting a start capacitor in series with the start winding. The windings of split-phase motors and capacitor motors are designed differently, and the insertion of a start capacitor in a split-phase motor would cause permanent damage to the motor.)

   B. Have start capacitor in series with start winding

   C. Have high starting torque

INFORMATION SHEET

D. Are efficient; draw little amperage

E. Have run capacitor in parallel with run winding

F. Generally have bleeder resistor on capacitor

IV. Capacitor-start induction-run (CSIR) motors (Transparency #1)

A. Are designed for heavier loads than split-phase motors

B. Must have a switch to remove start capacitor from circuit after starting

C. Are available in single or dual voltage

D. Have start capacitor only

V. Capacitor-start capacitor-run (CSR) motors (Transparency #2)

A. Have high starting torque

B. Are highly efficient; draw low amperage

C. Have high power factor

(NOTE: A run capacitor is used to improve power factor only.)

D. Have both start and run capacitors

E. Have increased capacitance at instant of start

F. Have start winding that stays in phase with run winding

(NOTE: In-phase operation enables the start winding to help the load requirements of the run winding.)

VI. Permanent split capacitor (PSC) motors (Transparency #3)

A. Have no centrifugal switch in open-drive motors

B. Have low starting torque

C. Have no motor-starting relay

D. May reverse direction of rotation

E. Have run capacitor only

INFORMATION SHEET

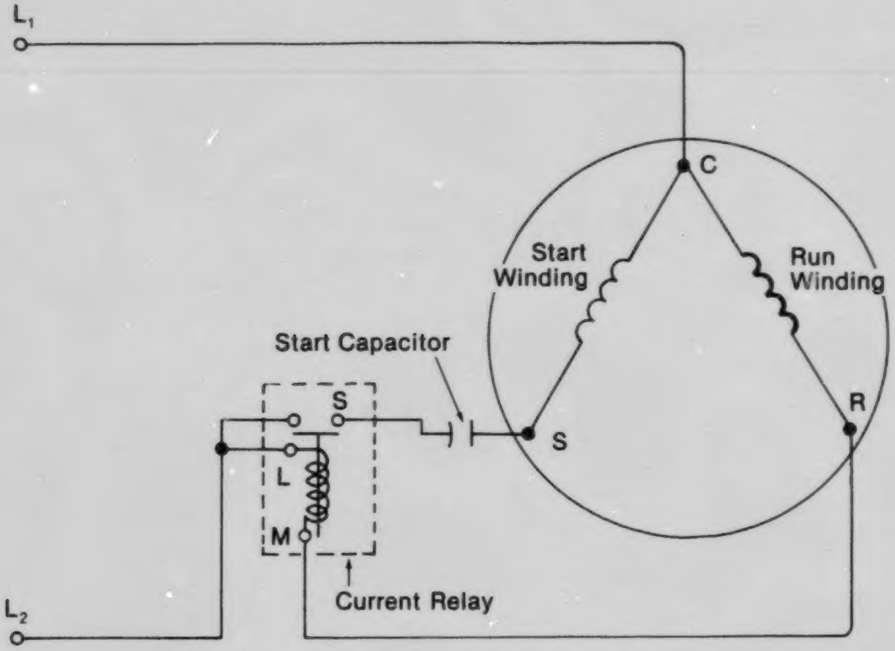
F. May add potential relay and start capacitor for increased starting torque

(NOTE: The addition of a potential relay and a start capacitor to a PSC motor is referred to as a *hard start kit*.)

VII. Wiring diagrams of CSIR, CSR, and PSC motors (Figures 1-3; Transparencies #1-#3)

A. CSIR motor

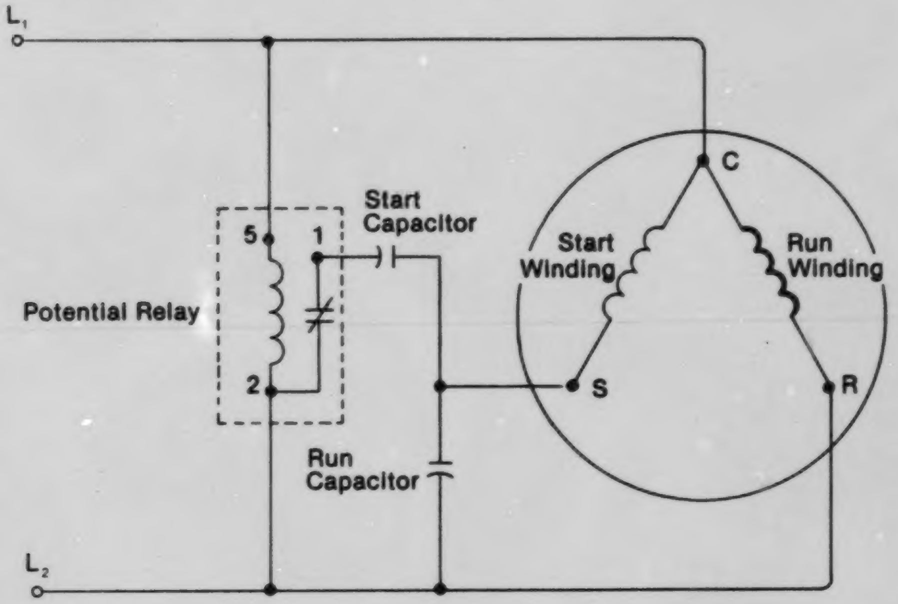
FIGURE 1


L_1
C
Start Winding
Run Winding
Start Capacitor
S
S
R
L
M
Current Relay
L_2

INFORMATION SHEET

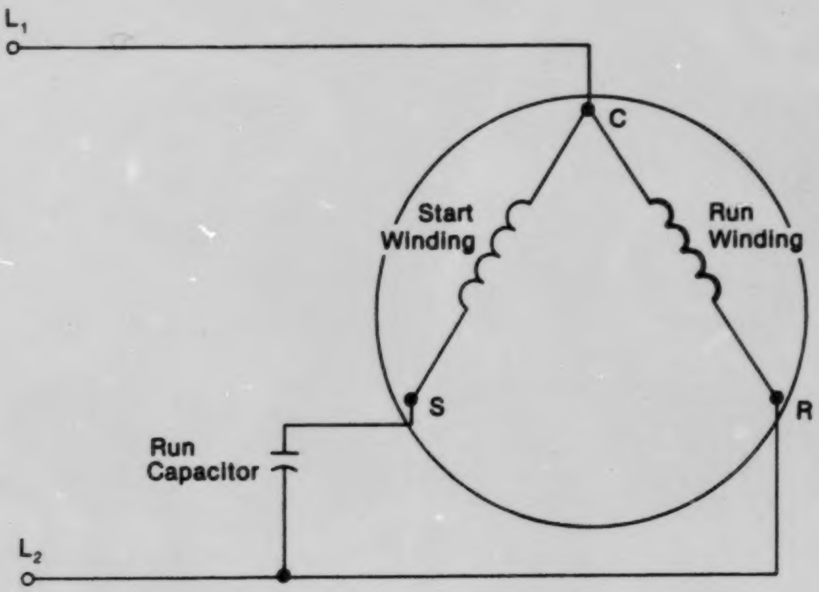
B. CSR motor

FIGURE 2

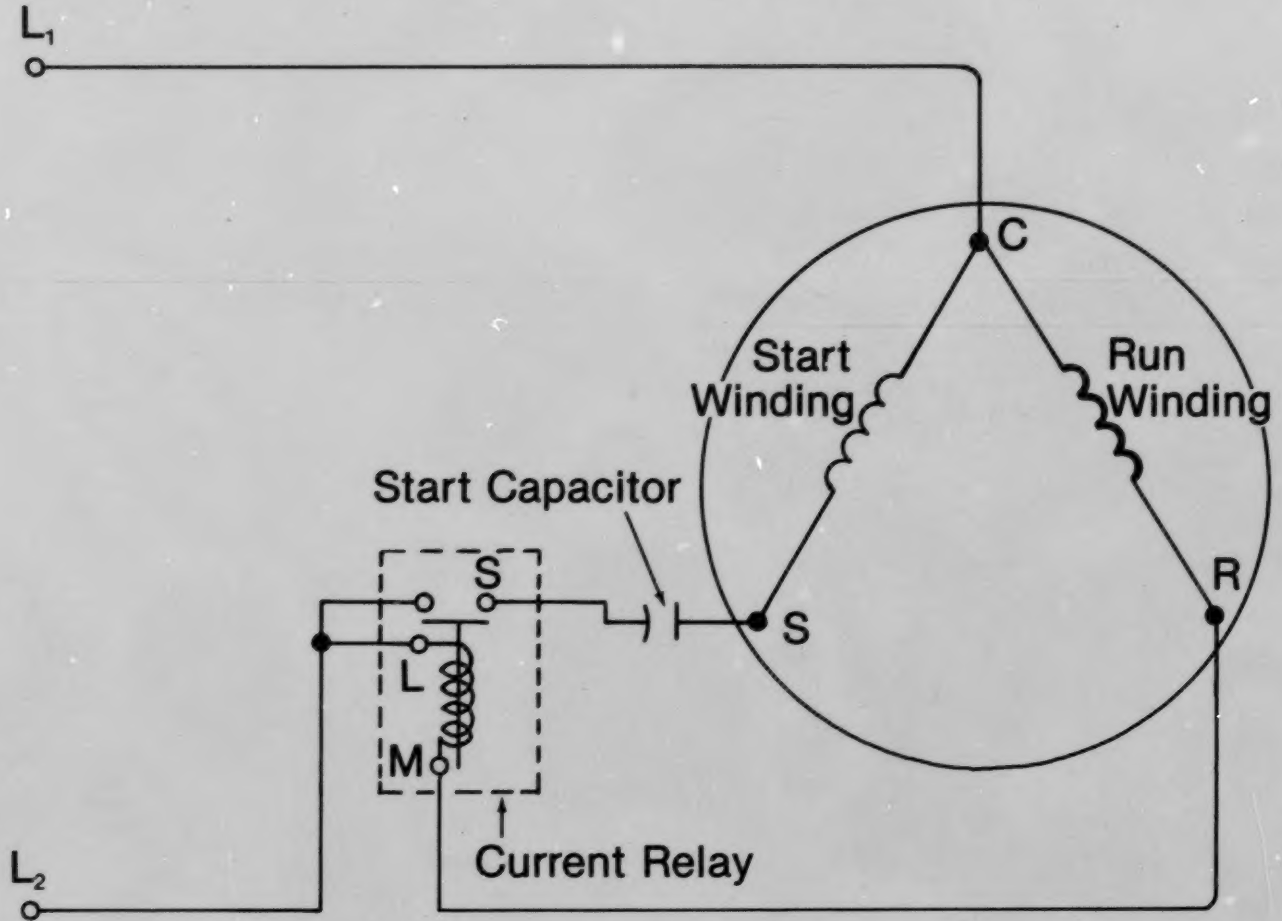

L1
L2
5
1
2
Potential Relay
Start Capacitor
Run Capacitor
C
Start Winding
Run Winding
S
R

C. PSC motor

FIGURE 3


L1
L2
C
Start Winding
Run Winding
S
R
Run Capacitor

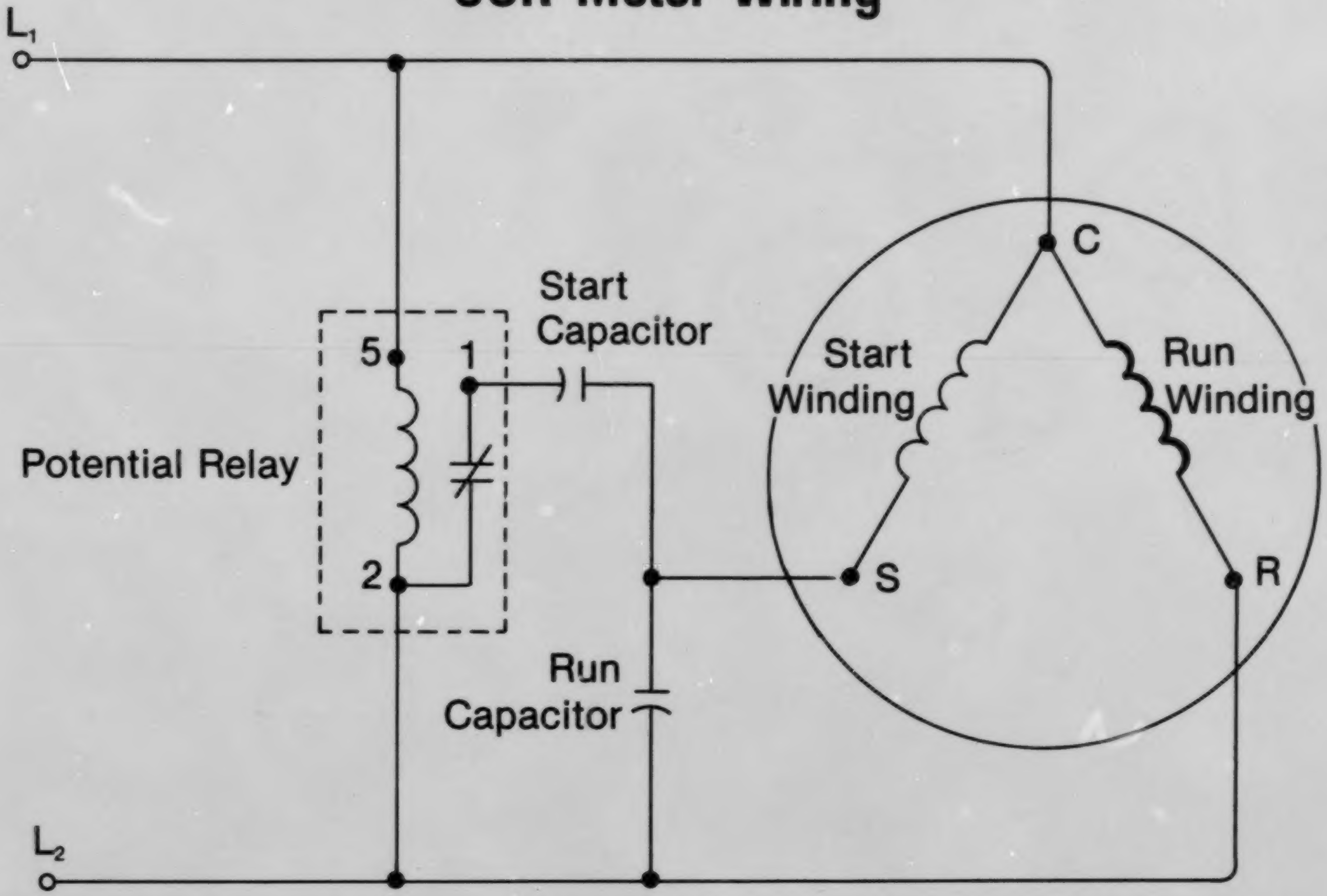
CSIR Motor Wiring


L_1
C
Start Winding
Run Winding
Start Capacitor
S
S
R
L
M
S
Current Relay
L_2

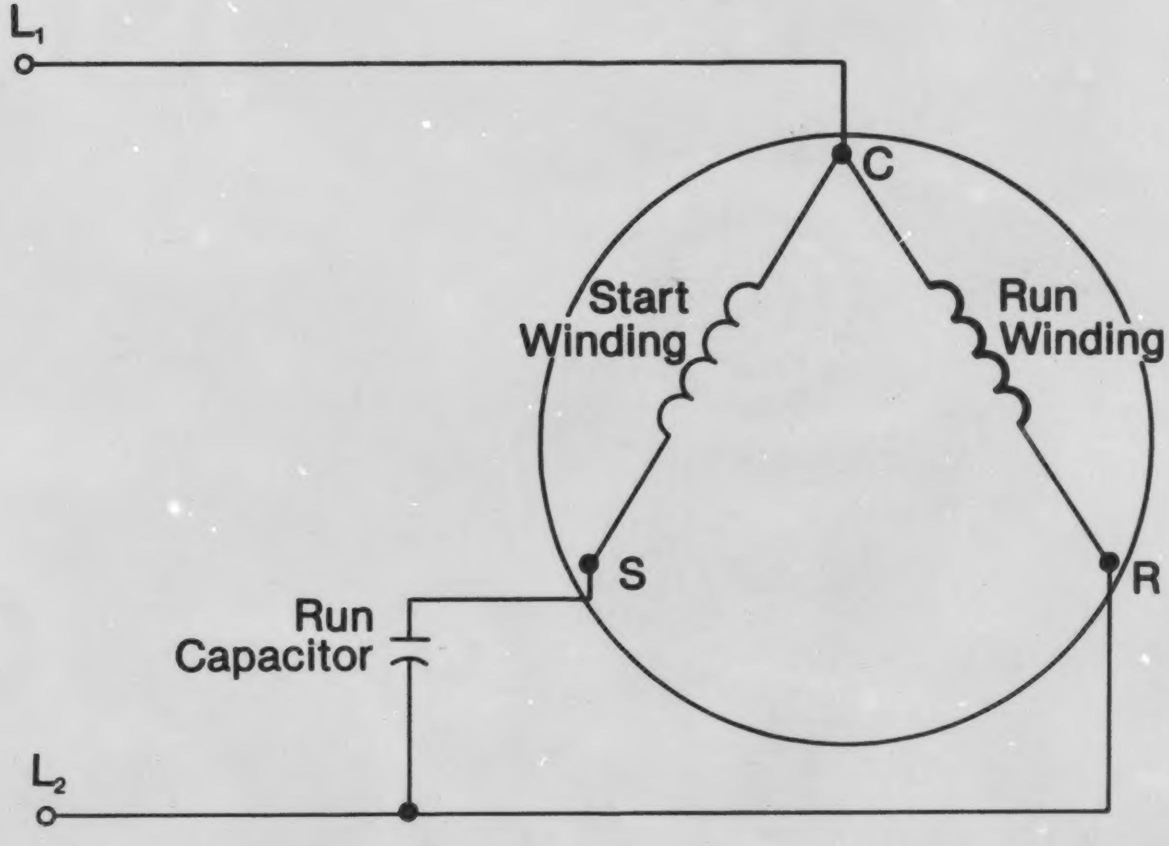
295

296

CSR Motor Wiring


L1
L2
Potential Relay
5
1
2
Start Capacitor
Run Capacitor
Start Winding
Run Winding
C
S
R

PSC Motor Wiring


L_1
C
Start Winding
Run Winding
S
R
Run Capacitor
L_2

CAPACITOR MOTORS
UNIT IV

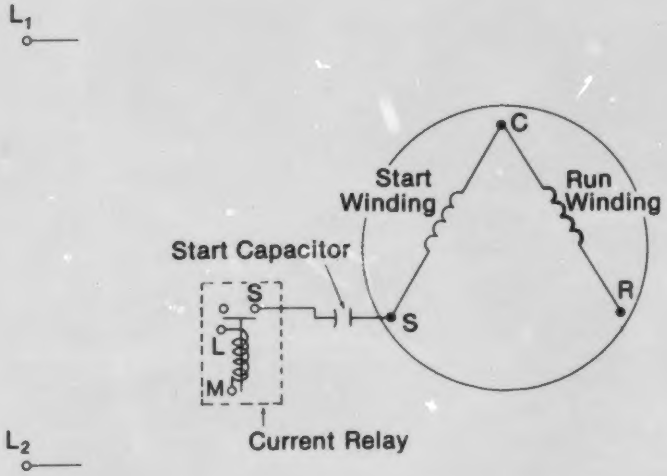
ASSIGNMENT SHEET #1 — COMPLETE WIRING DIAGRAMS FOR CAPACITOR MOTORS

NAME ______________________________ SCORE ______________

An electrical technician must be able to rewire motors that have been disconnected. The following diagrams are typical of motors found in the industry today.

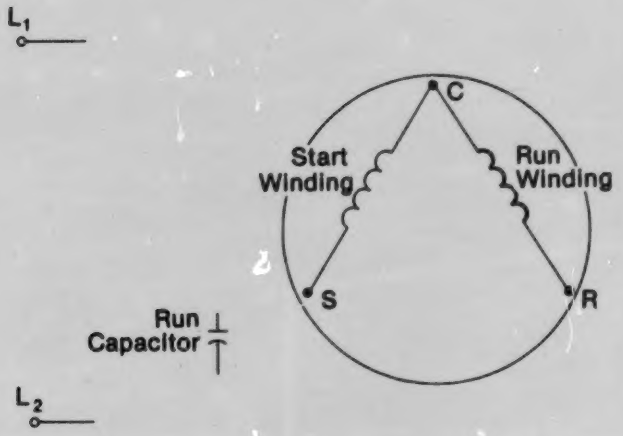
Complete the wiring for each of the following wiring diagrams.

A.

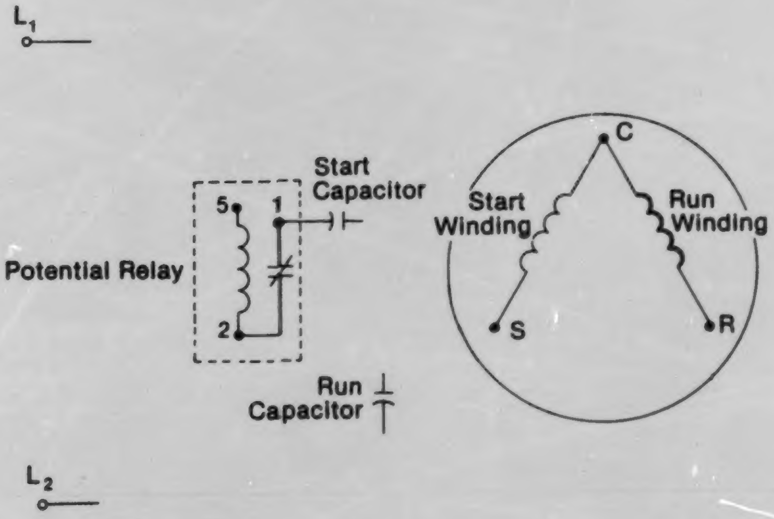

L_1
C
Start Winding
Run Winding
Start Capacitor
S
S
L
M
R
Current Relay
L_2

ASSIGNMENT SHEET #1

B.


L1
C
Start Winding
Run Winding
S
R
Run Capacitor
L2

C.

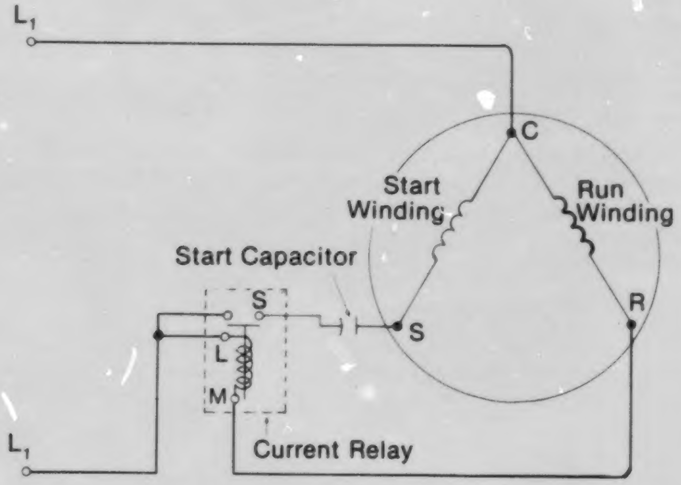

L1
C
Start Capacitor
5
1
Potential Relay
2
Start Winding
Run Winding
S
R
Run Capacitor
L2

CAPACITOR MOTORS
UNIT IV

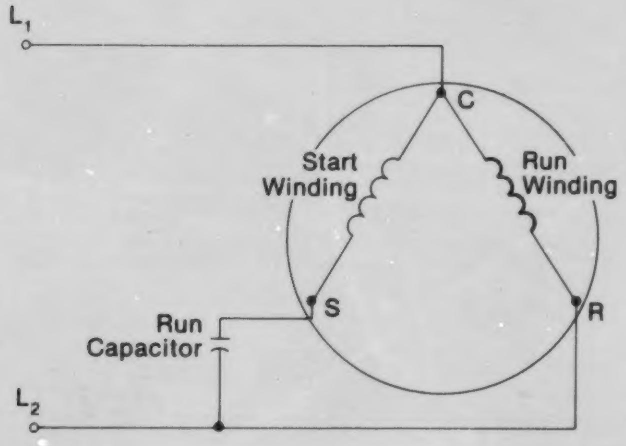
ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.

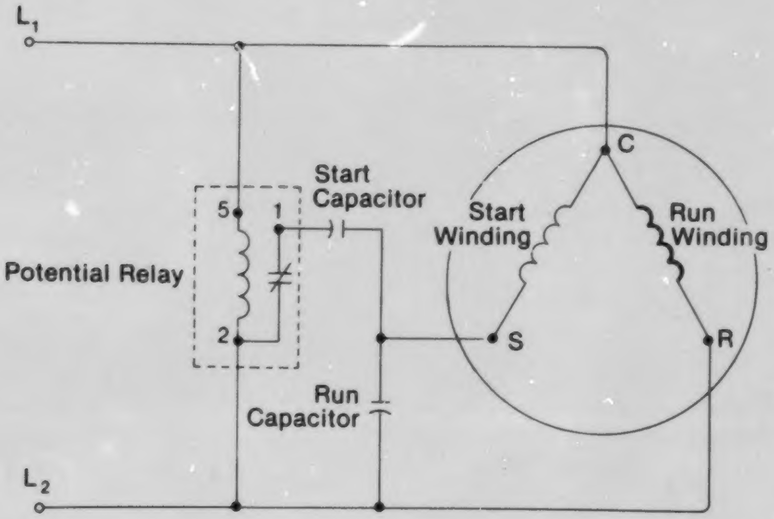

L1
C
Start Winding
Run Winding
Start Capacitor
S
S
R
L
M
L1
Current Relay

B.


L1
C
Start Winding
Run Winding
S
R
Run Capacitor
L2

ANSWERS TO ASSIGNMENT SHEETS

C.


L1
L2
Potential Relay
5
1
2
Start Capacitor
Run Capacitor
Start Winding
Run Winding
C
S
R

CAPACITOR MOTORS
UNIT IV

JOB SHEET #1 — TEST CAPACITORS WITH AN OHMMETER

I. Equipment and materials

A. 1,000-ohm ohmmeter with leads

B. Six or more start or run capacitors with clean terminals

C. Bleeder resistor with attached leads, approximately 75 ohms

(NOTE: The TIF-CT-660 capacitor tester has proven to be a good, inexpensive tool for these tests; however, ohmmeters may also be used.)

D. Eye protection

II. Procedure

A. Put on eye protection

B. Apply bleeder resistor across capacitor terminals long enough to be sure that capacitor is discharged

C. Set ohmmeter on R × 1,000 range

D. Set ohmmeter leads and zero instrument

E. Test for ground on run capacitors

1. Connect one ohmmeter lead to case

2. Touch other lead to capacitor terminal

(NOTE: If indicator moves toward zero, capacitor is probably bad and should be discarded. No movement of indicator indicates that unit is not grounded.)

F. Test for open and charging ability

1. Discharge capacitor completely

2. Connect one lead to one capacitor terminal

(NOTE: Make a good connection.)

JOB SHEET #1

3. While watching ohmmeter, firmly contact other capacitor terminal with second lead

   (NOTE: If the capacitor is good, the ohmmeter indicator will make a sudden move toward zero ohms, then stop and move less rapidly to the high resistance end of scale as the capacitor takes a charge from the voltage applied by the ohmmeter.)

4. Discharge capacitor and repeat test several times.

   (NOTE: If capacitor is open, the ohmmeter indicator will not move. If capacitor is shorted, the instrument will indicate zero or low resistance. If this occurs, discard the unit.)

G. Repeat test procedure on each capacitor

(NOTE: Destroy bad units to prevent their reinstallation. Show your work to the instructor for evaluation and comments.)

H. Clean work area; return equipment and materials to their proper places

CAPACITOR MOTORS
UNIT IV

JOB SHEET #2 — REVERSE A CAPACITOR MOTOR

I. Equipment and materials

   A. Capacitor motor

   B. Standard screwdriver, medium size

   C. Combination wrench set

   D. Small socket wrench set

   E. Terminal markers

   F. Lock and key for switch

   G. Terminal lugs

   H. Eye protection

II. Procedure

(NOTE: Capacitor motors reverse in the same manner as split-phase motors.)

   A. Put on eye protection

   B. Open power supply switch; check blades open and lock switch in open position

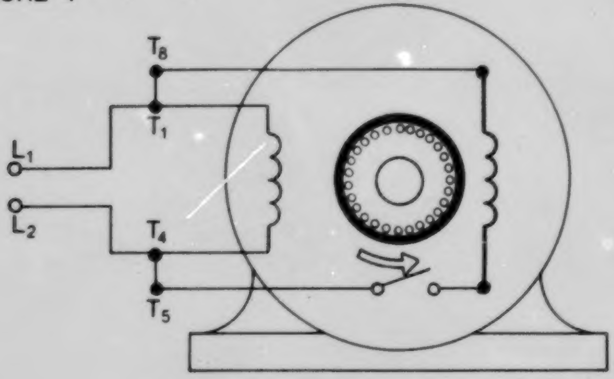
   C. Disconnect motor from power supply

JOB SHEET #2

D. Disconnect leads at motor; mark leads

(NOTE: Make note of lead location before disconnecting, and determine direction of rotation. See Figure 4.)

FIGURE 4

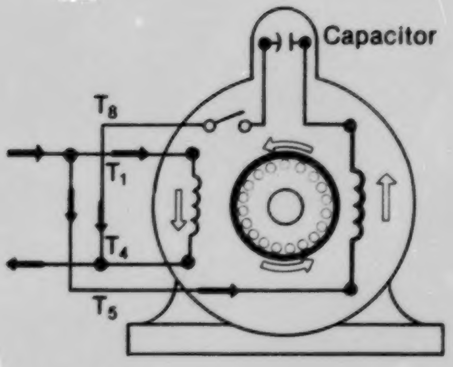


E. Interchange leads T5 and T8 *or* T1 and T4

(NOTE: Never interchange both pairs of leads.)

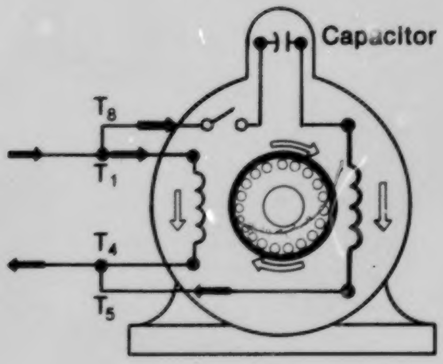
F. Note whether connection will cause motor to run clockwise or counterclockwise (Figures 5 and 6)

FIGURE 5



Counterclockwise
(Facing shaft end of motor)

FIGURE 6



Clockwise
(Facing shaft end of motor)

G. Clean work area; return equipment and materials to their proper places

CAPACITOR MOTORS
UNIT IV

JOB SHEET #3 — IDENTIFY RUN, COMMON, AND START TERMINALS ON A HERMETICALLY SEALED COMPRESSOR UNIT

I. Equipment and materials

A. Ohmmeter with leads and test clips

B. Three hermetically sealed compressor units

C. Paper to sketch terminals and record ohm readings

D. Pen or pencil

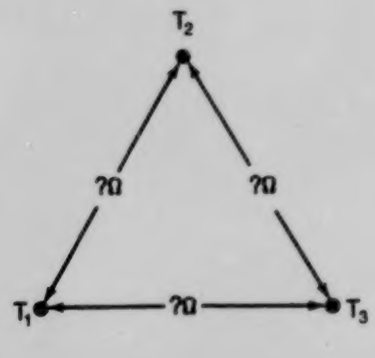
II. Procedure

(NOTE: The terminals on most units are *not* identified.)

A. Clean terminals to ensure good connections

B. Draw sketch of compressor unit electrical terminals as shown in Figure 7

FIGURE 7



C. Test, and record ohms between terminals 1 and 2

1 to 2 = ______________________ ohms

D. Test, and record ohms between terminals 2 and 3

2 to 3 = ______________________ ohms

E. Test, and record ohms between terminals 1 and 3

1 to 3 = ______________________ ohms

JOB SHEET #3

F. Analyze readings and label sketch as in Figures 8-10

FIGURE 8

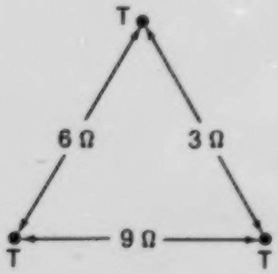


FIGURE 9

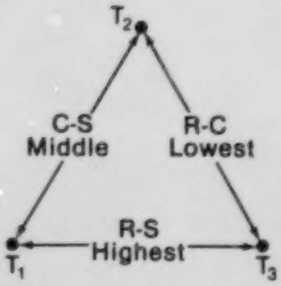
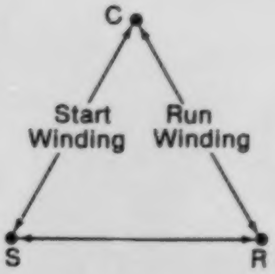

T_2
C-S Middle
R-C Lowest
R-S Highest
T_1
T_3

FIGURE 10


C
Start Winding
Run Winding
S
R

(NOTE: The run winding has larger wire, so it has the lowest resistance [R is common to highest and lowest readings]. The start winding has smaller wire and more terminals, so it has a higher reading [S is common to highest and middle readings]. The combined resistance of run and start windings is measured between R and S, so it gives the highest reading [C is common to middle and lowest readings].)

G. Repeat steps A through F on at least two more compressor units

(NOTE: Show your results to the instructor.)

H. Clean work area; return equipment and materials to their proper places

CAPACITOR MOTORS
UNIT IV

JOB SHEET #4 — TEST CURRENT RELAY

I. Equipment and materials

  A. Ohmmeter

  B. CSIR motor

  C. Screwdriver

  D. Needlenose pliers

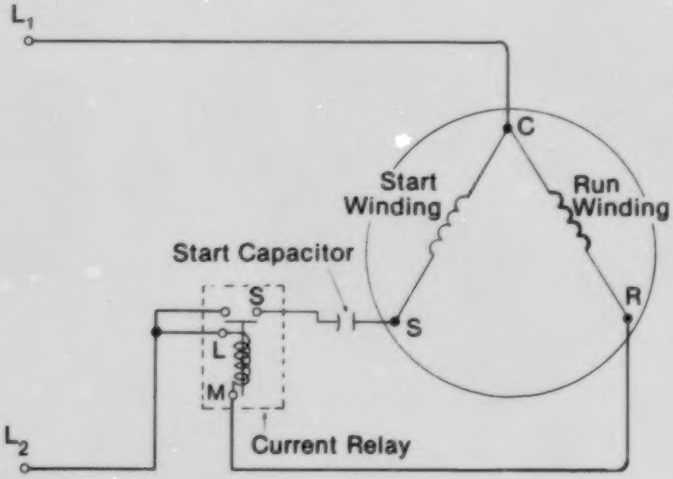
  E. Wire nuts

II. Procedure

  A. Disconnect voltage supply to motor and lock open

  B. Wire motor as shown in Figure 11

FIGURE 11


L_1
C
Start Winding
Run Winding
Start Capacitor
S
S
R
L
M
L_2
Current Relay

  C. Disconnect wires on S terminals, and insulate the wires with wire nuts

  D. Connect ohmmeter leads to S terminals

  E. Set ohmmeter on the R × 1 scale

JOB SHEET #4

F. Turn motor on and watch ohmmeter; if ohmmeter shows zero ohms, current relay is good; if ohmmeter does not move, relay is bad and must be replaced

(NOTE: Motor should be run only long enough to check ohmmeter, usually thirty seconds maximum.)

G. If relay is bad, replace it with a new one

H. If relay is good, reconnect wires to terminals

I. Lock off power to motor

J. Disconnect motor from supply voltage conductors

(NOTE: Report your findings and repairs to instructor; have instructor evaluate your work.)

K. Clean work area; put away equipment and materials

CAPACITOR MOTORS
UNIT IV

JOB SHEET #5 — TEST POTENTIAL RELAY

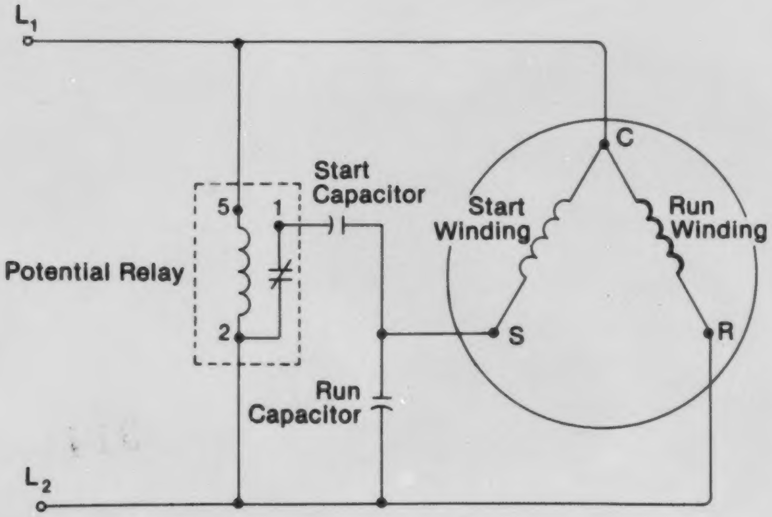
I. Equipment and materials

- A. Screwdriver
- B. Needlenose pliers
- C. CSR motor
- D. Voltmeter

II. Procedure

- A. Disconnect voltage supply to motor and lock open
- B. Wire motor as shown in Figure 12

FIGURE 12


L1
C
Start Capacitor
5
1
Start Winding
Run Winding
Potential Relay
2
S
R
Run Capacitor
L2

- C. Place voltmeter on appropriate scale for supply voltage
- D. Hook up voltmeter leads to terminals #1 and #2

JOB SHEET #5

E. Turn on voltage and start motor

F. Check voltmeter; reading should be within 80 percent of supply voltage

Volts = ____________________

G. Turn off motor and lock power off

H. Reset meter for ohms R × 1 scale

I. Meter should read zero ohms

Ohms = ____________________

(NOTE: If readings are not within 80 percent of voltage and zero ohms, potential relay is bad.)

J. Disconnect motor and meter

K. Clean work area; put away equipment and materials

CAPACITOR MOTORS
UNIT IV

TEST

NAME ________________________________ SCORE ____________

1. Match terms associated with capacitor motors to their correct definitions. Write the correct numbers in the blanks.

_____a. Magnet relay installed in parallel with load; operates due to voltage applied to coil

_____b. Magnet relay installed in series with load; operates when current reaches a predetermined value, or drops out when current drops too low

_____c. Relay that operates due to temperature changes

_____d. High resistance resistor attached between capacitor terminals to drain off the electrical charge

_____e. Motor designed to operate on two voltages

_____f. Motor that uses a start capacitor and/or a run capacitor in the electrical circuit

_____g. Motor that is sealed in the airtight dome with the compressor

1. Potential relay
2. Capacitor motor
3. Hermetic motor
4. Bleeder resistor
5. Current relay
6. Dual-voltage motor
7. Thermal relay

2. Name types of capacitor motors.

a. ____

b. ____

c. ____

3. Describe characteristics of capacitor motors.

____

____

____

____

____

____

TEST

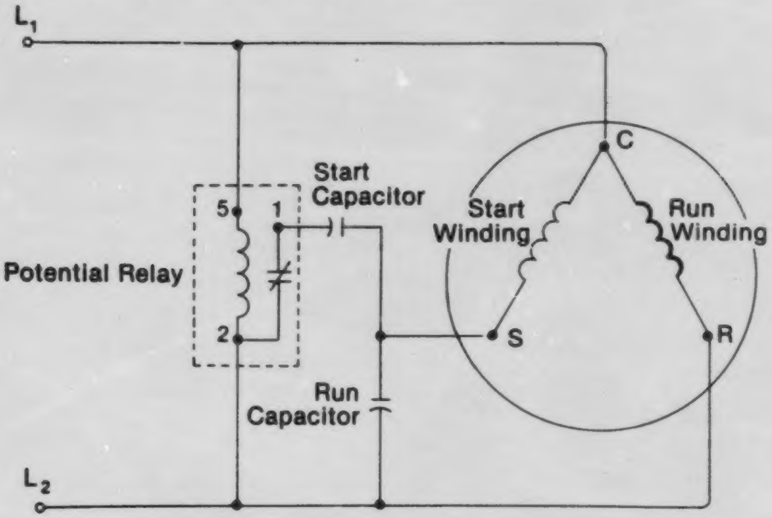
4. Describe capacitor-start induction-run (CSIR) motors.

5. Describe capacitor-start capacitor-run (CSR) motors.

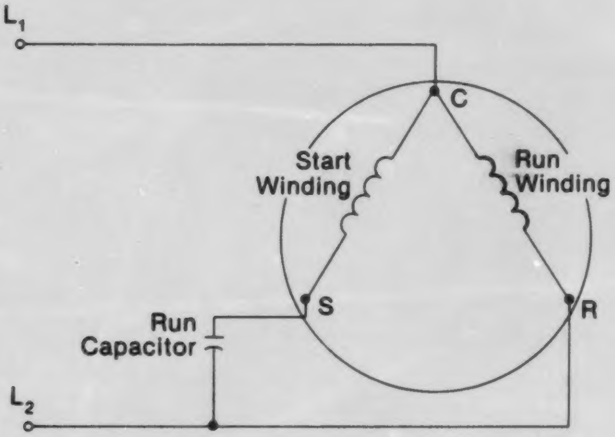
6. Describe permanent split capacitor (PSC) motors.

TEST

7. Identify the wiring diagrams of CSIR, CSR, and PSC motors.

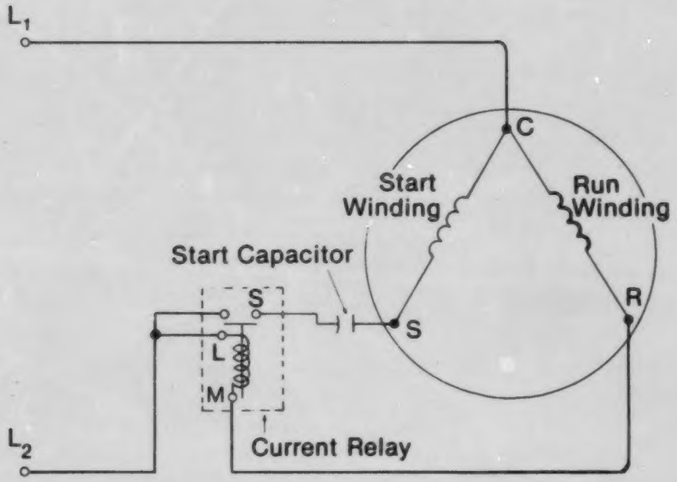

L1
L2
Potential Relay
5
1
2
Start Capacitor
Run Capacitor
Start Winding
Run Winding
C
S
R

a. ______________________________


L1
L2
C
Start Winding
Run Winding
S
R
Run Capacitor

b. ______________________________

TEST


L1
C
Start Winding
Run Winding
Start Capacitor
S
L
M
S
R
L2
Current Relay

c. ______________________________

(NOTE: Test questions 8 and 9 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

8. Complete wiring diagrams for capacitor motors.

9. Demonstrate the ability to

   a. Test capacitors with an ohmmeter.

   b. Reverse a capacitor motor.

   c. Identify run, common, and start terminals on a hermetically sealed compressor unit.

   d. Test current relay.

   e. Test potential relay.

CAPACITOR MOTORS
UNIT IV

ANSWERS TO TEST

1. a. 1
   b. 5
   c. 7
   d. 4
   e. 6
   f. 2
   g. 3

2. a. Capacitor-start induction-run (CSIR)
   b. Capacitor-start capacitor-run (CSR)
   c. Permanent split capacitor (PSC)

3. Description should include the following
   a. Are essentially the same design as split-phase motors but parts are not interchangeable
   b. Have start capacitor in series with start winding
   c. Have high starting torque
   d. Are efficient; draw little amperage
   e. Have run capacitor in parallel with run winding
   f. Generally have bleeder resistor on capacitor

4. Description should include the following
   a. Are designed for heavier loads than split-phase motors
   b. Must have a switch to remove start capacitor from circuit after starting
   c. Are available in single or dual voltage
   d. Have start capacitor only

ANSWERS TO TEST

5. Description should include the following
   a. Have high starting torque
   b. Are highly efficient; draw low amperage
   c. Have high power factor
   d. Have both start and run capacitors
   e. Have increased capacitance at instant of start
   f. Have start winding that stays in phase with run winding

6. Description should include the following
   a. Have no centrifugal switch in open-drive motors
   b. Have low starting torque
   c. Have no motor-starting relay
   d. May reverse direction of rotation
   e. Have run capacitor only
   f. May add potential relay and start capacitor for increased starting torque

7. a. CSR
   b. PSC
   c. CSIR

8. Evaluated to the satisfaction of the instructor

9. Performance skills evaluated to the satisfaction of the instructor

THREE-PHASE MOTORS
UNIT V

UNIT OBJECTIVE

After completing this unit, the student should be able to test a three-phase delta-connected motor and a three-phase wye-connected motor. The student should also be able to wire a motor for dual voltages. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with three-phase motors.
2. Name the major types of three-phase motors.
3. Select from a list the electrical characteristics of three-phase motors.
4. Distinguish between a schematic drawing of a delta-wound motor and a schematic drawing of a wye-wound motor.
5. Distinguish among characteristics of the different types of three-phase motors.
6. Describe the procedure for reversing the rotation of a three-phase motor.
7. Name typical supply voltages for three-phase motors.
8. Identify dual-voltage schematics and terminal connections.
9. Match windings to their proper configurations and voltages.
10. Make proper connections on three-phase motors.
11. Demonstrate the ability to
    a. Test a three-phase delta-connected motor.
    b. Test a three-phase wye-connected motor.
    c. Wire a motor for dual voltages.

THREE-PHASE MOTORS
UNIT V

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Provide students with objective sheet.

   C. Discuss unit and specific objectives. State need for knowledge in each area.

   D. Provide students with information, assignment, and job sheets.

   E. Discuss information, assignment, and job sheets.

      1. Discuss terms and definitions, using Information Sheet, Section I. Show students samples of motor parts to help students visualize some of the terms.

      2. Discuss major types of three-phase motors, using Information Sheet, Sections II through VII, and Transparencies #1 through #5 as well as actual models in shop to point out physical characteristics of the motors.

      3. Discuss procedure for reversing motors, typical supply voltages, and terminal connections, using Information Sheet, Section VIII, Transparencies #6 and #7, and Job Sheet #3. Demonstrate motor winding hookups and various voltage supplies in the shop.

   F. Give test.

   G. Reteach and retest if necessary.

II. Instructional materials

   A. Objective sheet

   B. Suggested activities

   C. Information sheet

   D. Transparency masters

      1. TM #1 — Delta-Wound Motor

      2. TM #2 — Wye-Wound Motor (Single Speed)

SUGGESTED ACTIVITIES

3. TM #3 — Synchronous Motor
4. TM #4 — Squirrel-Cage Rotor
5. TM #5 — Wound-Rotor Motor
6. TM #6 — Dual-Voltage Three-Phase Motor Showing Possible Six, Nine, and Ten Leads
7. TM #7 — Dual-Voltage Three-Phase Motor Showing Possible Twelve Leads

E. Assignment sheets

1. Assignment Sheet #1 — Match Windings to Their Proper Configurations and Voltages
2. Assignment Sheet #2 — Make Proper Connections on Three-Phase Motors

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Test a Three-Phase Delta-Connected Motor
2. Job Sheet #2 — Test a Three-Phase Wye-Connected Motor
3. Job Sheet #3 — Wire a Motor for Dual Voltages

H. Test

I. Answers to test

III. Unit references

A. Anderson, Edwin P., and Rex Miller. *Electric Motors*, 3rd ed. Indianapolis, Indiana: Audel Publishing, 1977.

B. Hubert, Charles. *Preventive Maintenance of Electrical Equipment*, 2nd ed. New York: McGraw-Hill, 1969.

C. Kaiser, Joe. *Electrical Power*. South Holland, Illinois: Goodheart-Willcox Company, Inc., 1982.

D. Mazur, Glen, and Gary Rockis. *Electrical Motor Controls*. Alsip, Illinois: Technical Publishing, Inc., 1982.

THREE-PHASE MOTORS
UNIT V

INFORMATION SHEET

I. Terms and definitions

A. Adjustable autotransformer — Transformer in which parts of one winding are common to both the primary and the secondary circuits, and the output voltage is adjustable from zero to line voltage

(NOTE: A trade name for the adjustable autotransformer is *Variac*.)

B. Breakdown torque — Maximum torque a motor can develop without an abrupt drop in speed

C. Brush — Piece of carbon or graphite that is an internal part of a motor and rides on the commutator or slip rings to provide an electrical connection to the rotor

D. Delta — Three-phase circuit in which the windings are connected to form a completely closed loop (Transparency #1)

E. Dual-voltage motor — Motor capable of being wired to run at two different voltages

F. Power factor — Ratio of active power to apparent power

G. Slip — Difference between synchronous speed (N_s) and rotor speed (N_r)

(NOTE: This value is expressed as a percentage of synchronous speed.)

H. Squirrel-cage rotor — Rotor consisting of two discs connected along their circumference with copper bars that create a shunted circuit

(NOTE: The squirrel-cage motor derives its name from its squirrel-cage rotor.)

I. Starting torque — Percentage of force above running torque; applies only during start-up of motor

J. Synchronous — In step or in phase as applied to currents; constant speed to which an alternating-current motor adjusts itself

K. Torque — Force that produces a rotating or twisting action

(NOTE: A unit of torque is expressed in foot-pounds.)

L. Variable resistor — Wire-wound resistor in which the resistance may be selected through a given range by turning the control shaft

INFORMATION SHEET

M. Wound-rotor induction motor — Motor with a rotor in which the windings are insulated and connections to the rotor windings are made through carbon brushes

(NOTE: Wound-rotor motors are sometimes called *slip-ring motors*.)

N. Wye — Three-phase circuit in which the windings are connected to form the shape of the letter "Y" (Transparency #2)

II. Major types of three-phase motors

A. Synchronous

B. Squirrel-cage rotor

C. Wound rotor

III. Electrical characteristics of three-phase motors

A. Require no starting devices

EXAMPLES: Capacitors, start windings

B. Contain set of poles for each phase

C. Have high starting torque

D. Have high power factor

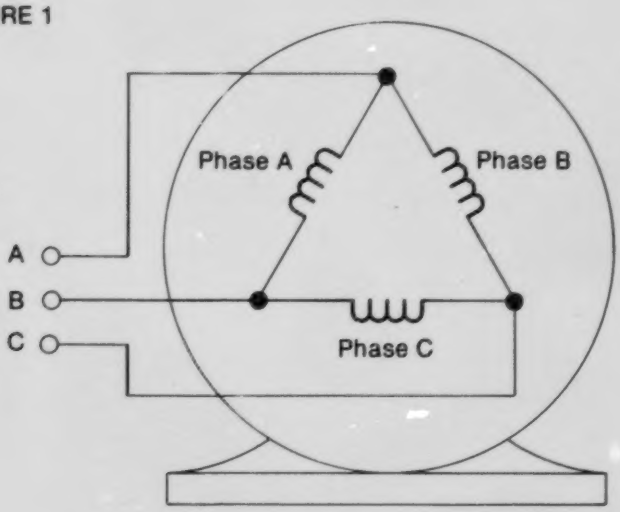
E. Are easily reversed

INFORMATION SHEET

IV. Schematic drawings of delta-wound and wye-wound motors (Figures 1 and 2; Transparencies #1 and #2)

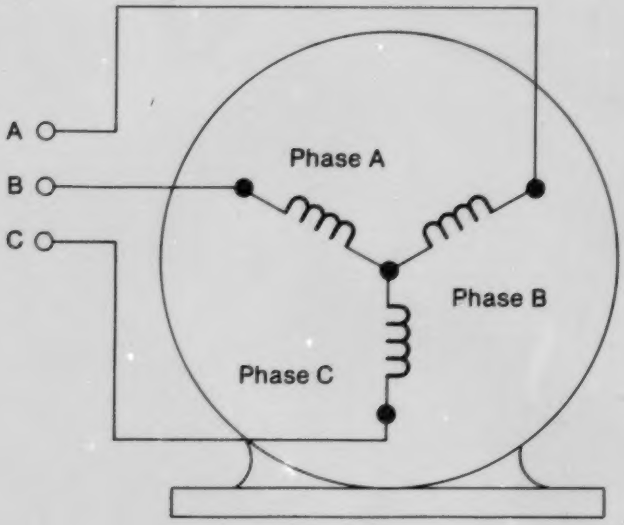
A. Delta wound

FIGURE 1


Phase A
Phase B
A
B
C
Phase C

B. Wye wound

FIGURE 2


A
B
C
Phase A
Phase B
Phase C

INFORMATION SHEET

V. Characteristics of the different types of three-phase motors

A. Synchronous motor (Transparency #3)

(NOTE: Synchronous motors are used for high-horsepower or low-speed applications.)

1. Has standard stator

2. Uses direct current as source of excitation for rotor

EXAMPLES: Mounted on rotor shaft, starting torque

3. Is nonexcited if small and of low torque

4. Has high power factor

(NOTE: A synchronous motor can be used to correct a lagging power factor.)

5. Runs at exactly synchronous speed

B. Squirrel-cage motor (Transparency #4)

(NOTE: A high percentage of the motors in use today are squirrel-cage induction motors. They are used in most major household appliances.)

1. Has induction start and run

2. Speed is determined by frequency and number of poles

3. Has low to medium starting torque

4. Runs slower than synchronous speed

C. Wound-rotor motor (Transparency #5)

(NOTE: Wound-rotor motors are used mostly on heavy equipment that requires high starting torque, smooth acceleration, and variable speeds, such as cranes, hoists, and elevators, where frequent starting, stopping, and reversing are required.)

1. Has slip rings and brushes

2. Combines high starting torque with low starting current

3. May have manual or automatic motor controls

EXAMPLES: Variable resistor, tapped autotransformer, drum controller

INFORMATION SHEET

4. Has variable starting torque, current, operating speed, and acceleration

5. Runs slower than synchronous speed

VI. Procedure for reversing the rotation of a three-phase motor — Rotation of any three-phase motor may be reversed by switching any two of the line-voltage leads

VII. Typical supply voltages for three-phase motors

A. 230-volt three-phase delta

B. 480-volt three-phase delta

C. 208-volt three-phase wye

D. 480-volt three-phase wye

VIII. Dual-voltage schematics and terminal connections (Figures 3-10; Transparencies #6 and #7; Assignment Sheets #1 and #2)

A. Delta-wound nine-lead motor (high voltage)

(NOTE: On a typical 230/480-volt dual-voltage motor, the 230-volt windings would wire in parallel and the 480-volt windings would wire in series, as shown in Figures 3 and 4.)

FIGURE 3 Schematic Connection

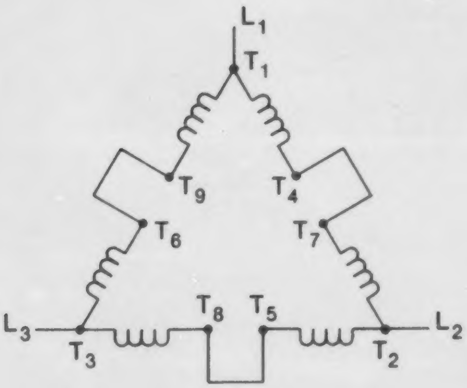
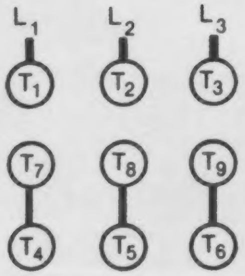


FIGURE 4 Terminal Connection



INFORMATION SHEET

B. Delta-wound nine-lead motor (low voltage)

FIGURE 5 Schematic Connection

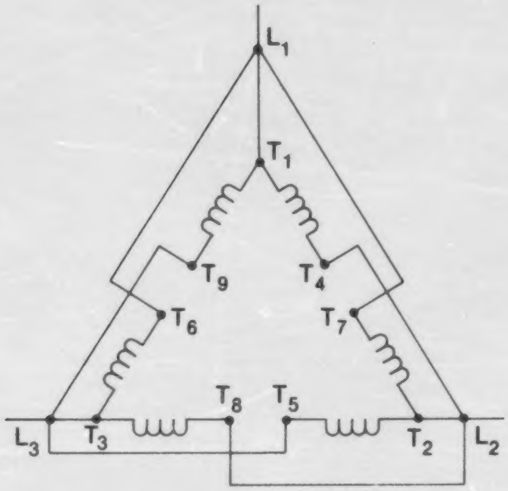
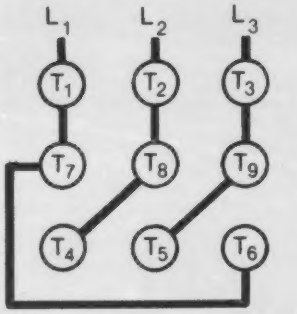

L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

FIGURE 6 Terminal Connection


L_1
L_2
L_3
T_1
T_2
T_3
T_7
T_8
T_9
T_4
T_5
T_6

EXAMPLE: Connections for a delta-wound dual-voltage motor (Table 1)

TABLE 1

Voltage	L1	L2	L3	Tie Together		
Low	T1 T6 T7	T2 T4 T8	T3 T5 T9			
High	T1	T2	T3	T4 T7	T5 T8	T6 T9

INFORMATION SHEET

C. Wye-wound nine-lead motor (high voltage)

FIGURE 7 Schematic Connection

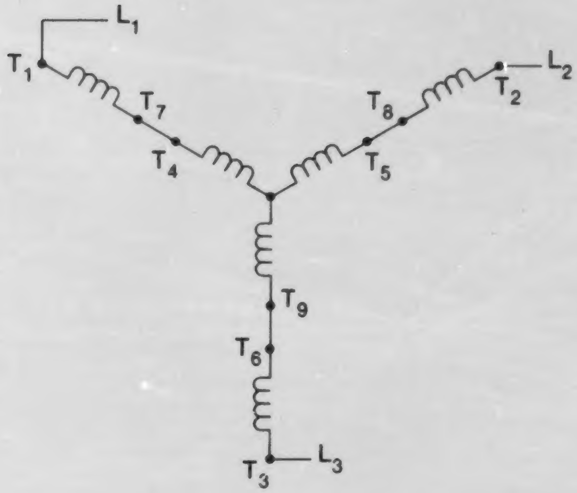
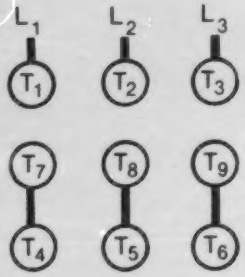

L1
T1
T7
T4
T8
L2
T2
T5
T9
T6
T3
L3

FIGURE 8 Terminal Connection


L1
L2
L3
T1
T2
T3
T7
T8
T9
T4
T5
T6

D. Wye-wound nine-lead motor (low voltage)

FIGURE 9 Schematic Connection

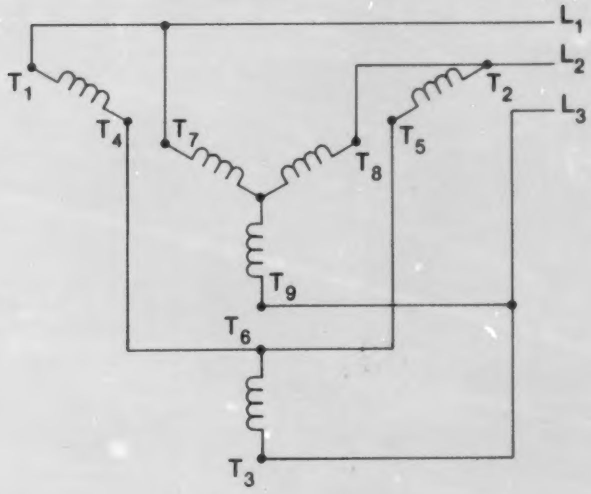
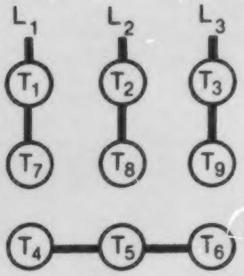

L1
L2
L3
T1
T4
T7
T8
T5
T2
T9
T6
T3

FIGURE 10 Terminal Connection


L1
L2
L3
T1
T2
T3
T7
T8
T9
T4
T5
T6

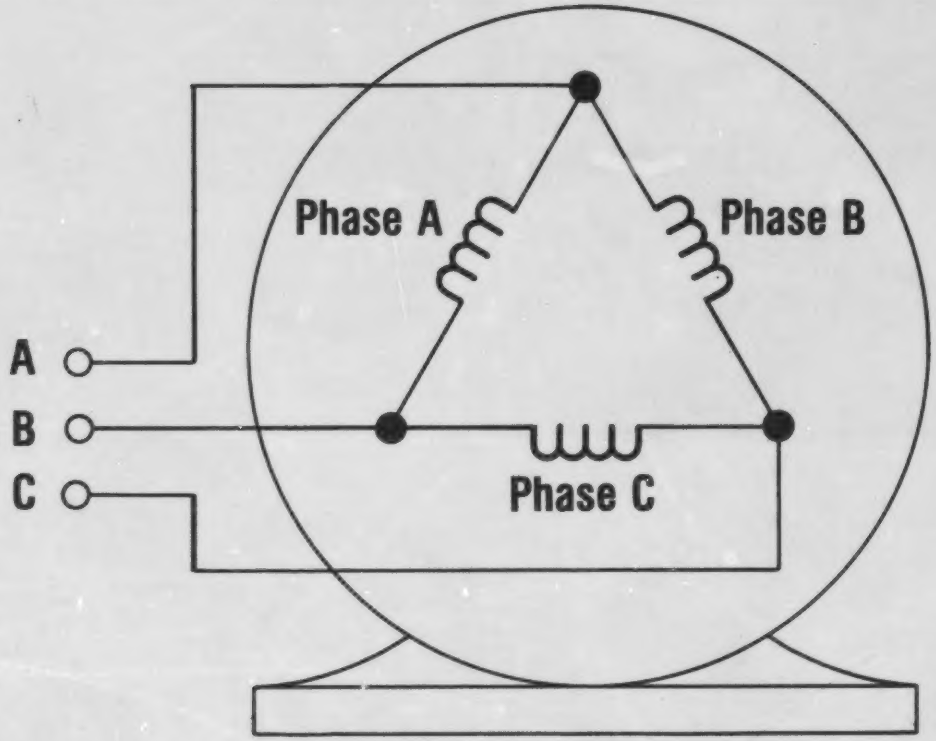
INFORMATION SHEET

EXAMPLE: Connections for a wye-wound dual-voltage nine-lead motor (Table 2)

TABLE 2

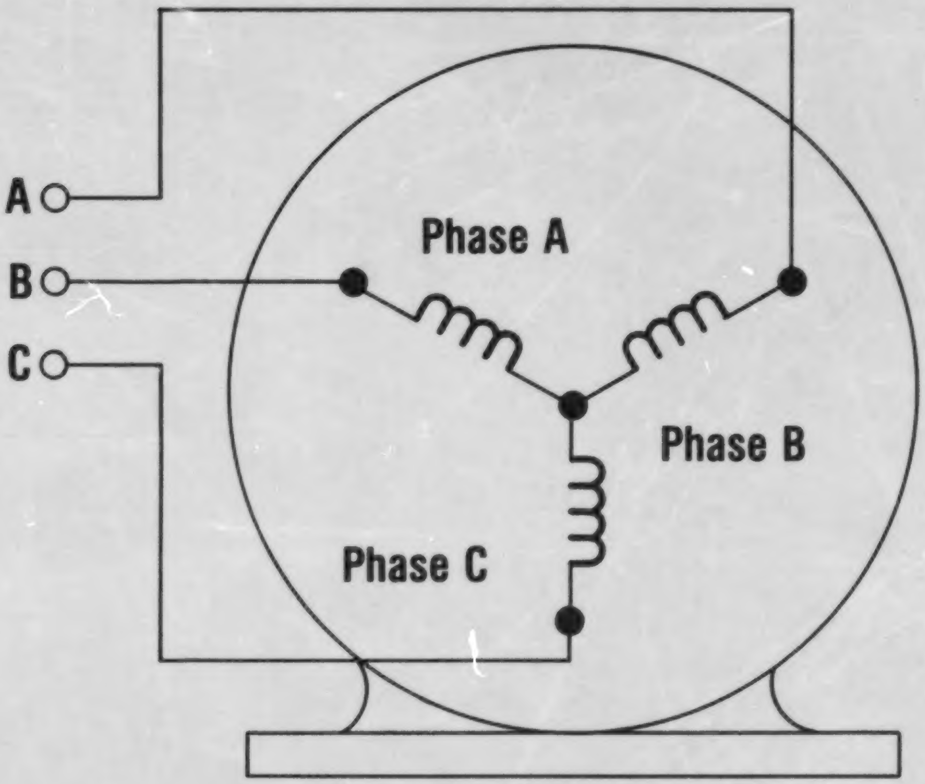
Voltage	L1	L2	L3	Tie Together		
Low	T1 T7	T2 T8	T3 T9		T4 T5 T6	
High	T1	T2	T3	T4 T7	T5 T8	T6 T9

Delta-Wound Motor

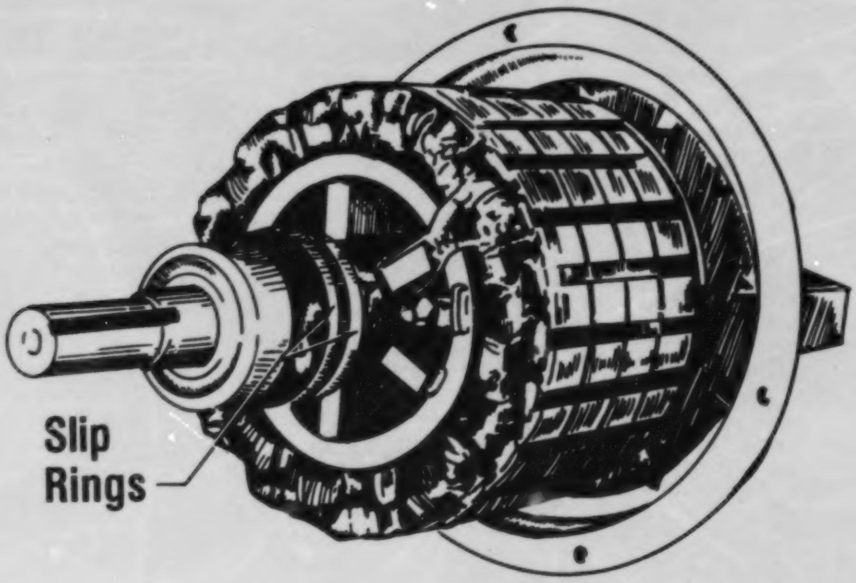

Phase A
Phase B
A
B
C
Phase C

Wye-Wound Motor

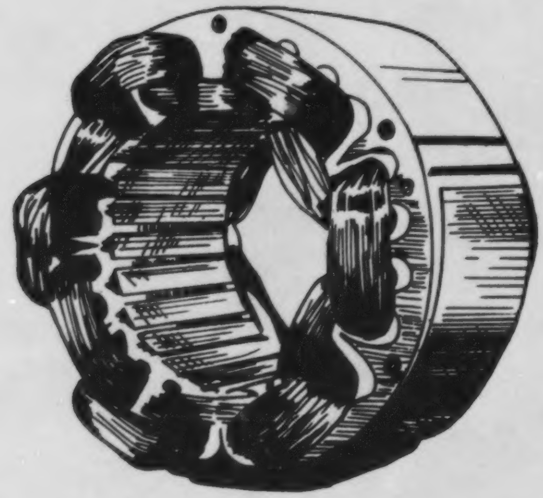
(Single Speed)


A
B
C
Phase A
Phase B
Phase C

Synchronous Motor

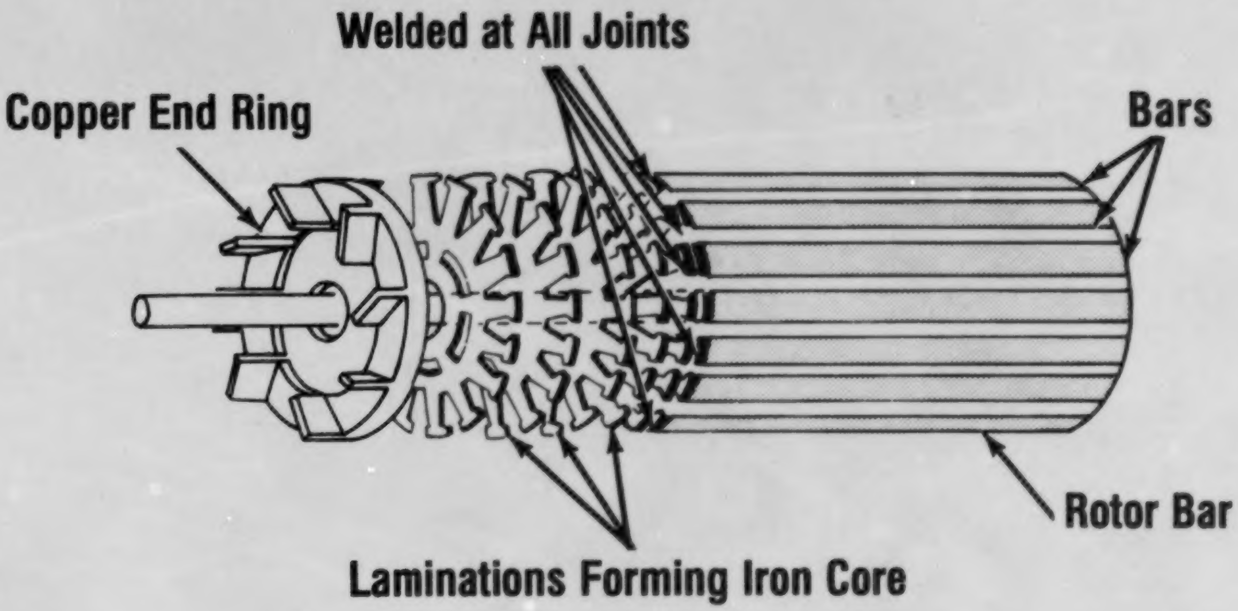


Rotor



Stator

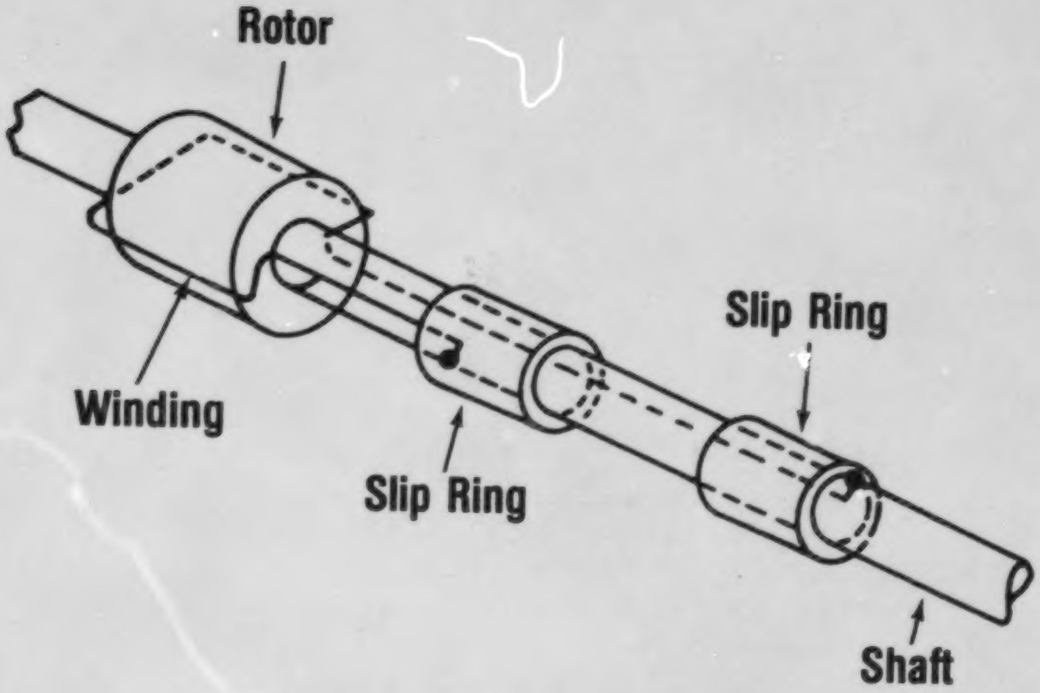
Squirrel-Cage Rotor


Welded at All Joints
Copper End Ring
Bars
Rotor Bar
Laminations Forming Iron Core

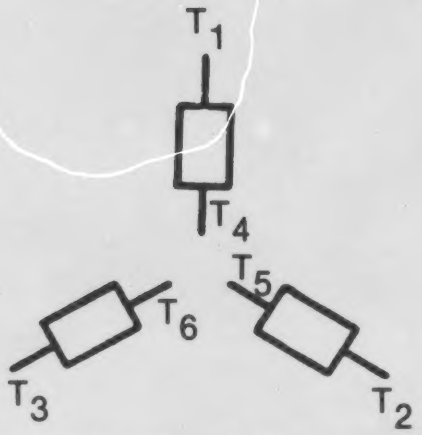
TM #4

IE - 193-B

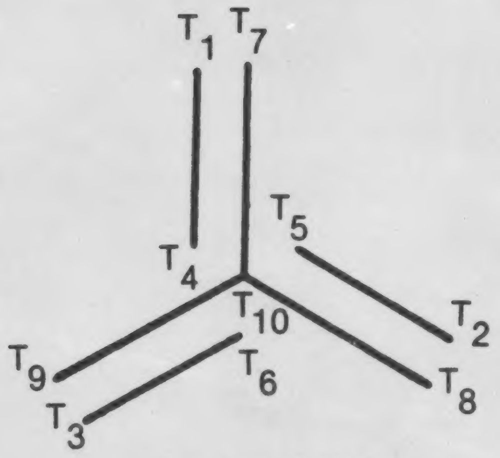
Wound-Rotor Motor


Rotor
Slip Ring
Winding
Slip Ring
Shaft

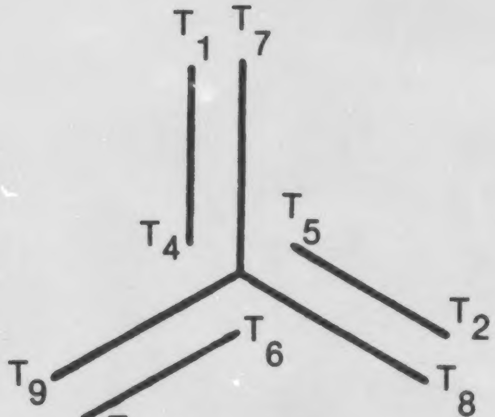
Dual-Voltage Three-Phase Motor Showing Possible Six, Nine, and Ten Leads


T_1
T_4
T_5
T_6
T_3
T_2

Six-Lead Wye

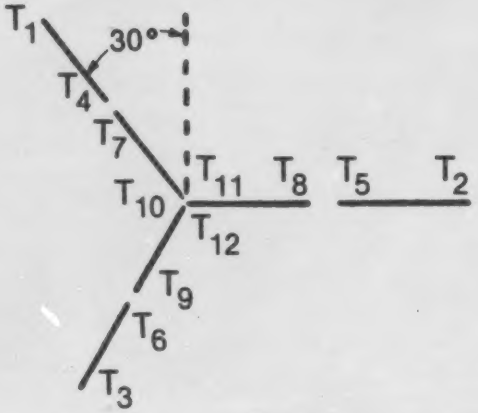

T_1
T_7
T_5
T_4
T_{10}
T_2
T_9
T_6
T_8
T_3

Ten-Lead Wye

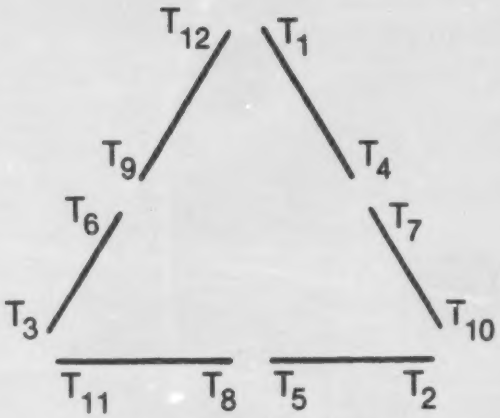

T_1
T_7
T_4
T_5
T_2
T_6
T_9
T_8
T_3

Nine-Lead Wye

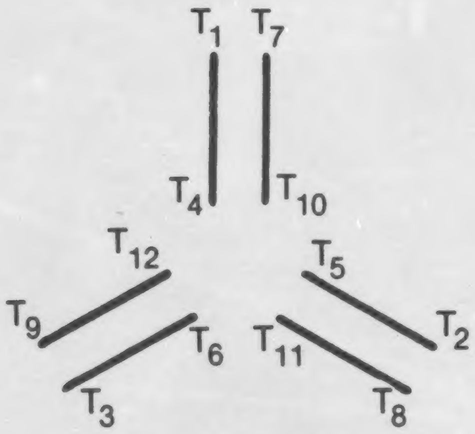
Dual-Voltage Three-Phase Motor Showing Possible Twelve Leads


T_1
30°
T_4
T_7
T_{10}
T_{11}
T_8
T_5
T_2
T_{12}
T_9
T_6
T_3

Twelve-Lead Wye (High Voltage)


T_{12}
T_1
T_9
T_4
T_6
T_7
T_3
T_{10}
T_{11}
T_8
T_5
T_2

Twelve-Lead Delta (High Voltage)


T_1
T_7
T_4
T_{10}
T_{12}
T_5
T_9
T_6
T_{11}
T_2
T_3
T_8

Twelve-Lead Wye (Low Voltage)

THREE-PHASE MOTORS
UNIT V

ASSIGNMENT SHEET #1 — MATCH WINDINGS TO THEIR PROPER CONFIGURATIONS AND VOLTAGES

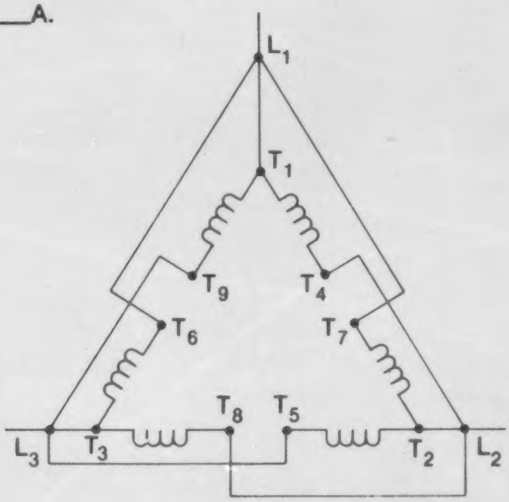
NAME ______________________________ SCORE ____________

Every electrical technician must be able to match winding connections to their proper configurations and voltages quickly and accurately.

Match each of the following schematics to their correct configurations and voltages. Write the correct numbers in the blanks.

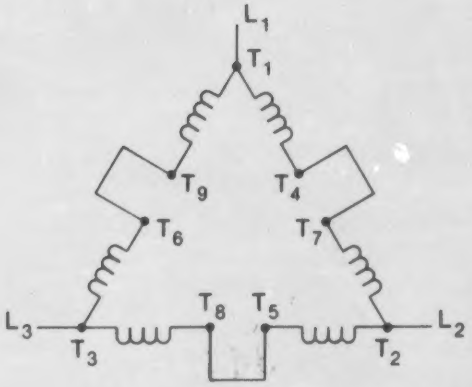
1. 480-volt three-phase delta
2. 208-volt three-phase wye
3. 480-volt three-phase wye
4. 230-volt three-phase delta

_____A.



L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

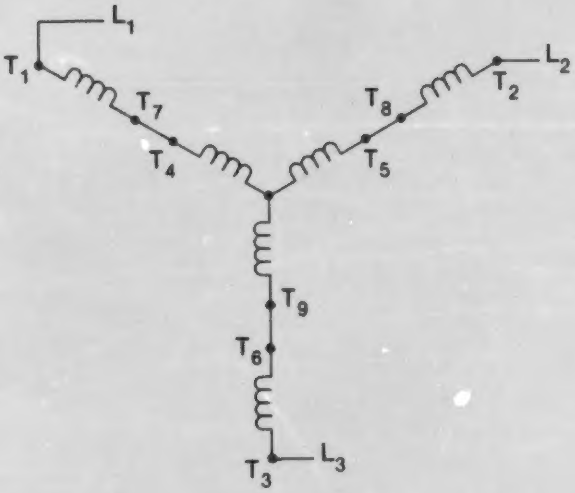
_____B.



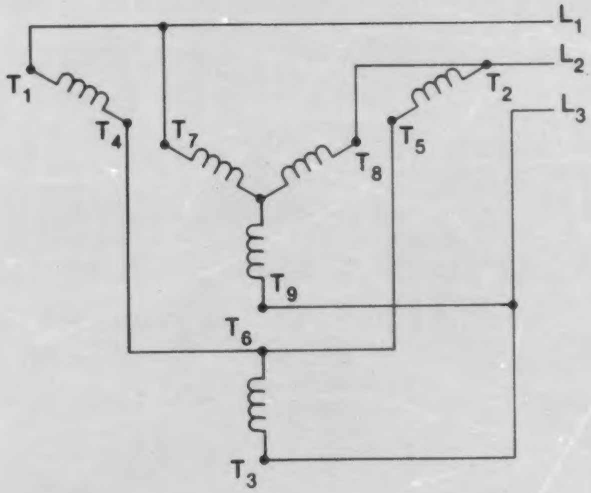
L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

ASSIGNMENT SHEET #1

_____C.


L1
T1
T7
T4
T8
T2
L2
T5
T9
T6
T3
L3

_____D.


L1
L2
L3
T1
T2
T4
T7
T5
T8
T9
T6
T3

THREE-PHASE MOTORS
UNIT V

ASSIGNMENT SHEET #2 — MAKE PROPER CONNECTIONS ON THREE-PHASE MOTORS

NAME ______________________________ SCORE ____________

A technician must be able to make proper connections on three-phase motors before he or she can test the motors. Furthermore, much practice is required before making connections on three-phase motors becomes second nature.

PART I

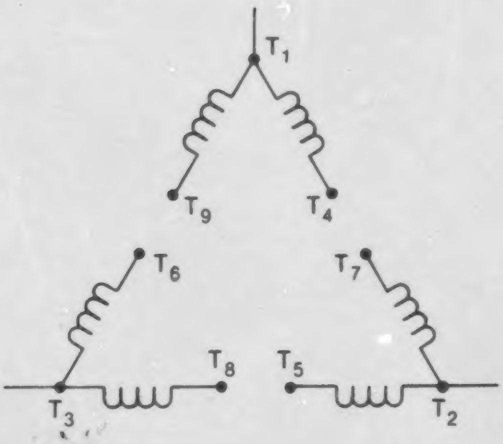
Make proper connections on three-phase delta motors. You may refer to Section VIII of the Information Sheet.

TABLE 3

Delta Connections

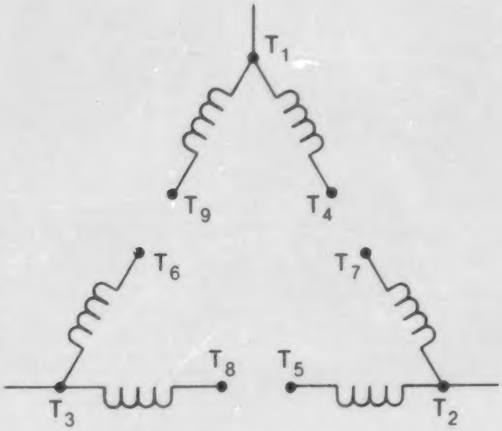
Voltage	L1	L2	L3	Tie Together		
Low	T1 T6 T7	T2 T4 T8	T3 T5 T9			
High	T1	T2	T3	T4 T7	T5 T8	T6 T9

A. Connect the following three-phase dual-voltage motor for low-voltage delta; use Table 3 above.



ASSIGNMENT SHEET #2

B. Connect the following three-phase dual-voltage motor for high-voltage delta; use Table 3 on the previous page.



PART II

Make proper connections on three-phase wye motors. You may refer to Section VIII of the Information Sheet.

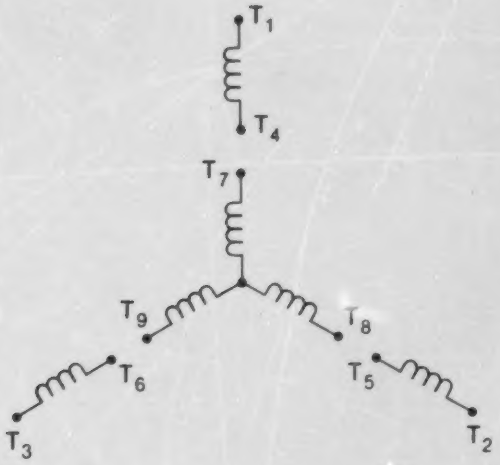
TABLE 4

Wye Connections

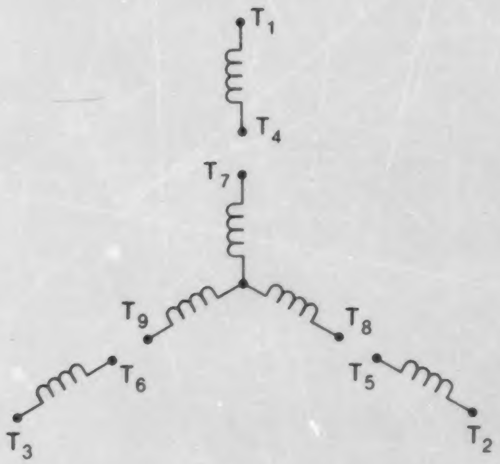
Voltage	L1	L2	L3	Tie Together		
Low	T1 T7	T2 T8	T3 T9		T4 T5 T6	
High	T1	T2	T3	T4 T7	T5 T8	T6 T9

ASSIGNMENT SHEET #2

A. Connect the following three-phase dual-voltage motor for low-voltage wye; use Table 4 on the previous page.


T_1
T_4
T_7
T_9
T_8
T_6
T_5
T_3
T_2

B. Connect the following three-phase dual voltage motor for high-voltage wye; use Table 4 on the previous page.


T_1
T_4
T_7
T_9
T_8
T_6
T_5
T_3
T_2

THREE-PHASE MOTORS
UNIT V

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 4

B. 1

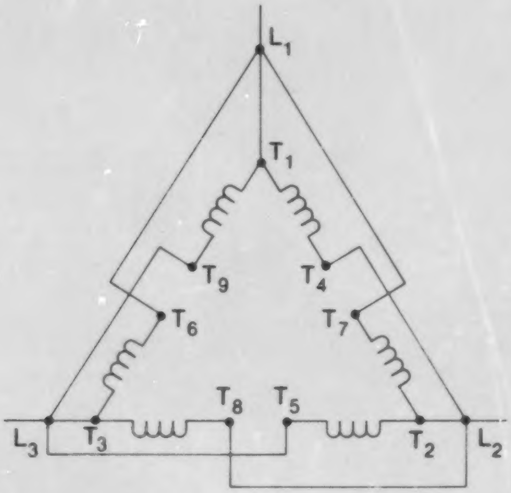
C. 3

D. 2

Assignment Sheet #2

Part I

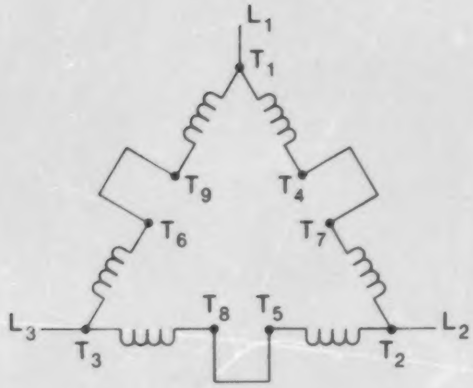
A.



L_1
T_1
T_9
T_4
T_6
T_7
T_8
T_5
L_3
T_3
T_2
L_2

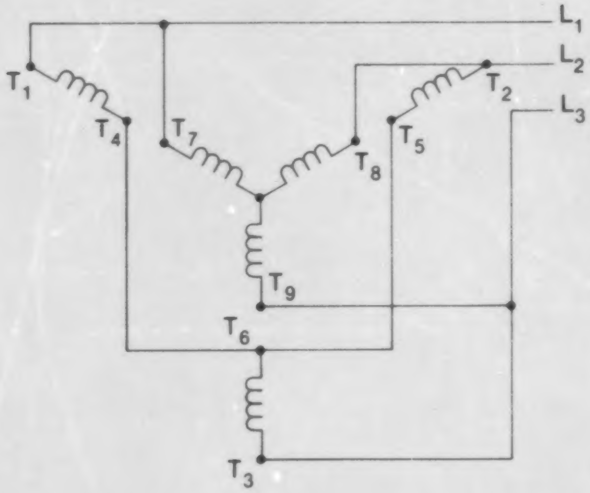
ANSWERS TO ASSIGNMENT SHEETS

B.


L1
T1
T9
T4
T6
T7
L3
T8
T5
L2
T3
T2

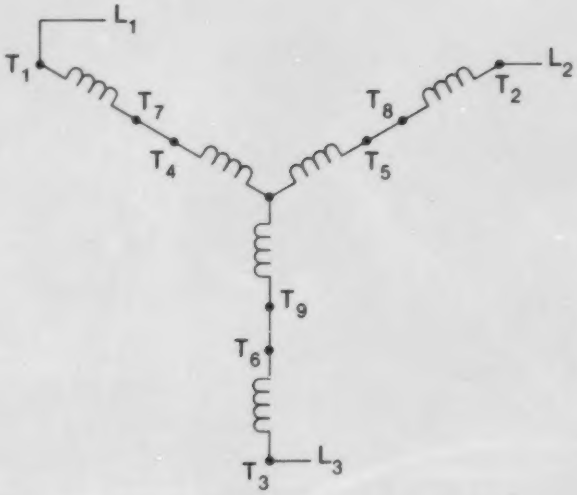
PART II

A.


L1
L2
T1
T2
L3
T4
T7
T5
T8
T9
T6
T3

ANSWERS TO ASSIGNMENT SHEETS

B.


L$_1$
T$_1$
T$_7$
T$_4$
T$_8$
T$_2$
L$_2$
T$_5$
T$_9$
T$_6$
T$_3$
L$_3$

THREE-PHASE MOTORS
UNIT V

JOB SHEET #1 — TEST A THREE-PHASE DELTA-CONNECTED MOTOR

I. Equipment and materials

A. Three-phase delta-connected motor

B. Multimeter

C. 500-VDC Megger

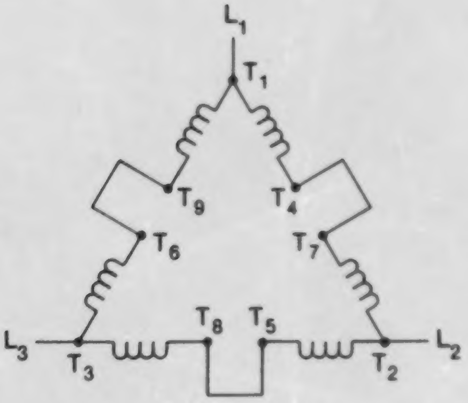
D. Standard screwdriver

E. Knife

F. Centrigrade thermometer

II. Procedure (Figure 11)

FIGURE 11



A. Place multimeter in ohms position on the R × 1 scale, and zero meter

JOB SHEET #1

B. Using ohmmeter, place leads on terminals T1 and T2 shown in Figure 11; record readings

(NOTE: Motor windings must be connected for high voltage with one corner of delta open.)

T1 to T2 = ____________________

C. Place leads on terminals T1 and T3; record reading

T1 to T3 = ____________________

D. Place leads on terminals T2 and T3; record reading

T2 to T3 = ____________________

E. Using recorded readings, determine if stator is open or shorted

(NOTE: All readings will be approximately equal if there is no open or short. Remember that you have two paths for current between each pair of phase leads, unless one corner of the delta is opened.)

F. Using 500-VDC Megger, connect both leads to a bare metal surface on stator

G. Start to turn crank while observing meter

(NOTE: Meter should hit zero instantly; if it does not, check connections and proper meter operation.)

H. Remove Megger hot lead from stator and connect to shorted motor terminals

I. Start to crank Megger slowly

J. If meter does not hit zero, continue to crank at about 120 rpm for approximately sixty seconds; record reading and temperature

Reading = ____________________

Motor temperature = ____________________

K. Using recorded reading, determine if motor is grounded or not grounded

(NOTE: A zero reading means that the motor is grounded. A low reading indicates that motor may have retained moisture. Motor must be dried before being returned to duty.)

L. Use checklist below and on the next page to analyze procedure for faults

_____T1, T2, T3 phase not open or shorted

_____Motor grounded

JOB SHEET #1

_____Motor not grounded

_____T1 phase open

_____T2 phase open

_____T3 phase open

_____T1 phase shorted

_____T2 phase shorted

_____T3 phase shorted

M. Clean work area; return equipment and materials to their proper places

THREE-PHASE MOTORS
UNIT V

JOB SHEET #2 — TEST A THREE-PHASE WYE-CONNECTED MOTOR

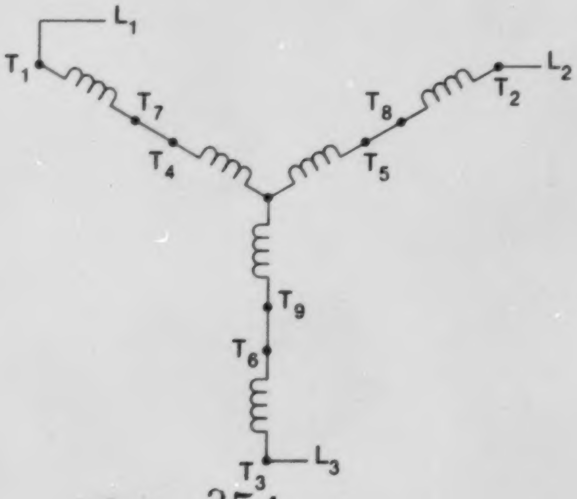
I. Equipment and materials

- A. Polyphase motor
- B. PS M-4 multimeter or equivalent
- C. 500-VDC Megger
- D. Scratch paper and pencil
- E. Standard screwdriver
- F. Needle-nosed pliers
- G. Wire strippers
- H. Lineman's pliers
- I. Centigrade thermometer

II. Procedure (Figure 12)

(NOTE: Before testing, be sure that motor is connected for high voltage.)

FIGURE 12



JOB SHEET #2

A. Place multimeter in ohms position on the R × 1 scale, and zero meter

B. Using ohmmeter, place leads on terminals T1 and T2 shown in Figure 12; record readings

T1 to T2 = ________________________________

C. Place leads on terminals T1 and T3; record reading

T1 to T3 = ________________________________

D. Place leads on terminals T2 and T3; record reading

T2 to T3 = ________________________________

E. Using recorded readings, determine if stator is open or shorted

(NOTE: All readings should be approximately equal.)

F. Using the 500-VDC Megger, connect both leads to bare metal surface on stator

G. Start to crank while observing meter

(NOTE: Meter should hit zero instantly; if not, check connections and proper operation.)

H. Remove Megger line lead from stator and connect to shorted motor terminals

I. Start to crank Megger slowly

J. If meter does not hit zero, continue to crank at about 120 rpm for approximately sixty seconds; record reading and temperature

Reading = ________________________________

Motor temperature = ________________________________

K. Using recorded readings, determine if motor is grounded or not grounded

L. Use the checklist below and on the following page to analyze procedure for faults

_____T1, T2, T3 phase not open or shorted

_____Motor grounded

_____Motor not grounded

JOB SHEET #2

_____T1 phase open

_____T2 phase open

_____T3 phase open

_____T1 phase shorted

_____T2 phase shorted

_____T3 phase shorted

M. Clean work area; and return equipment and materials to their proper places

THREE-PHASE MOTORS
UNIT V

JOB SHEET #3 — WIRE A MOTOR FOR DUAL VOLTAGES

I. Equipment and materials

   A. Dual-voltage motor

   B. Screwdriver

   C. Pliers

   D. Wire nuts

   E. Wire markers

II. Procedure

   A. Open motor lead connection box

   B. Separate leads

   C. Check motor plate for low-voltage connections

   D. Hook up leads as shown on motor plate

   E. Label leads that would go to L1, L2, and L3

   F. Tell instructor the voltage you wired the motor for; have instructor inspect your work

   G. Disconnect all leads

   H. Check motor plate for high-voltage connections

   I. Hook up leads as shown on motor plate

   J. Mark leads that would go to L1, L2, and L3

   (NOTE: Tell the instructor what voltage you set the motor up for; have instructor inspect your work.)

   K. Clean work area; return equipment and materials to their proper places

THREE-PHASE MOTORS
UNIT V

TEST

NAME ______________________________ SCORE ______________

1. Match to their correct definitions terms associated with three-phase motors. Write the correct numbers in the blanks. Definitions continue on the following page.

_____a. In step or in phase as applied to currents; constant speed to which an alternating-current motor adjusts itself

_____b. Rotor consisting of two discs connected along their circumference with copper bars that create a shunted circuit

_____c. Motor with a rotor in which the windings are insulated and connections to the rotor windings are made through carbon brushes

_____d. Transformer in which parts of one winding are common to both the primary and the secondary circuits, and the output voltage is adjustable from zero to line voltage

_____e. Piece of carbon or graphite that is an internal part of a motor and rides on the commutator or slip rings to provide an electrical connection to the rotor

_____f. Wire-wound resistor in which the resistance may be selected through a given range by turning the control shaft

_____g. Difference between synchronous speed (N_s) and rotor speed (N_r)

_____h. Force that produces a rotating or twisting action

_____i. Maximum torque a motor can develop without an abrupt drop in speed

_____j. Ratio of active power to apparent power

1. Variable resistor
2. Delta
3. Wound-rotor induction motor
4. Dual-voltage motor
5. Adjustable auto-transformer
6. Synchronous
7. Wye
8. Starting torque
9. Squirrel-cage rotor
10. Slip
11. Breakdown torque
12. Brush
13. Torque
14. Power factor

TEST

_____k. Three-phase circuit in which the windings are connected to form a completely closed loop

_____l. Three-phase circuit in which the windings are connected to form the shape of the letter "Y"

_____m. Motor capable of being wired to run at two different voltages

_____n. Percentage of force above running torque; applies only during start-up of motor

2. Name the major types of three-phase motors.

a. ____

b. ____

c. ____

3. Select from the following list the electrical characteristics of three-phase motors. Write an "X" in the blank before each correct answer.

_____a. Are easily reversed

_____b. Have high starting torque

_____c. Have low power factor

_____d. Contain set of poles for each phase

_____e. Require starting devices

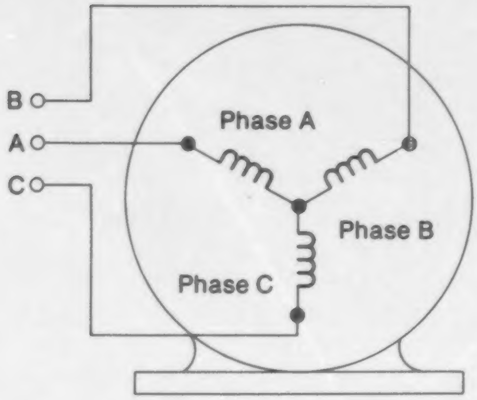
_____f. Have high power factor

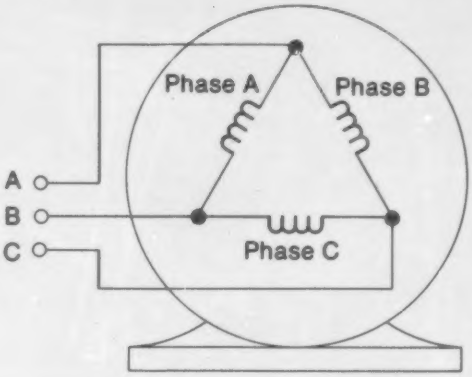
_____g. Contain set of poles for first phase

_____h. Require no starting devices

TEST

4. Distinguish between a schematic drawing of a delta-wound motor and a schematic drawing of a wye-wound motor. Place an "X" under the drawing of a delta-wound motor.





a. ______________________________ b. ______________________________

5. Distinguish among characteristics of the different types of three-phase motors. Write "SYN" in the blanks before characteristics of synchronous motors, "SQ" before characteristics of squirrel-cage motors, and "WR" before characteristics of wound-rotor motors. A blank may contain more than one answer. Characteristics continue on the next page.

__________a. Has induction start and run

__________b. Has high power factor

__________c. Has standard stator

__________d. Has slip rings and brushes

__________e. Has variable starting torque, current, operating speed, and acceleration

__________f. Uses direct current as source of excitation for rotor

__________g. Speed is determined by frequency and number of poles

__________h. May have manual or automatic motor controls

__________i. Has low to medium starting torque

TEST

__________j. Is nonexcited if small and of low torque

__________k. Runs at exactly synchronous speed

__________l. Runs slower than synchronous speed

__________m. Combines high starting torque with low starting current

6. Describe the procedure for reversing the rotation of a three-phase motor.

____

____

7. Name typical supply voltages for three-phase motors.

a. ____

b. ____

c. ____

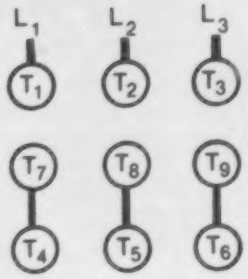
d. ____

8. Identify dual-voltage schematics and terminal connections. Write the correct numbers in the blanks. Schematics and terminal connections are continued on the following pages.

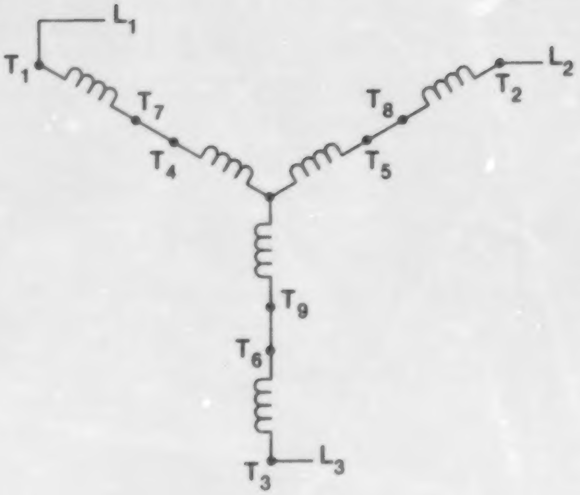
1. Delta-wound nine-lead motor (low voltage), terminal connection
2. Wye-wound nine-lead motor (high voltage), schematic connection
3. Wye-wound nine-lead motor (low voltage), terminal connection
4. Delta-wound nine-lead motor (low voltage), schematic connection
5. Delta-wound nine-lead motor (high voltage), schematic connection
6. Wye-wound nine-lead motor (high voltage), terminal connection
7. Wye-wound nine-lead motor (low voltage), schematic connection
8. Delta-wound nine-lead motor (high voltage), terminal connection

TEST

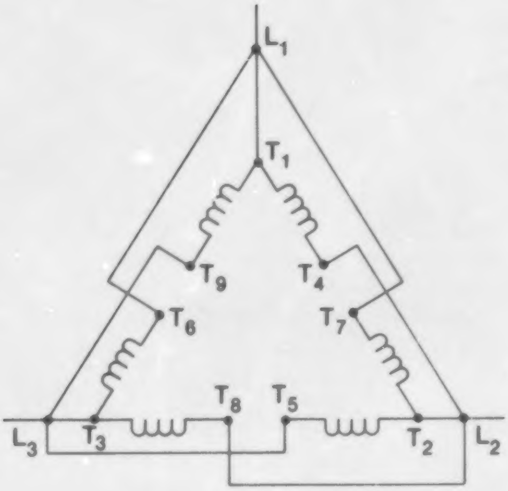
_____a.


L1
L2
L3
T1
T2
T3
T7
T8
T9
T4
T5
T6

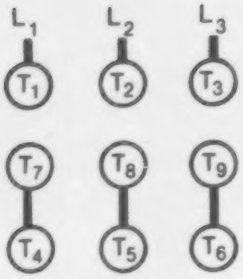
_____b.


L1
T1
T7
T4
T8
T2
L2
T5
T9
T6
T3
L3

_____c.

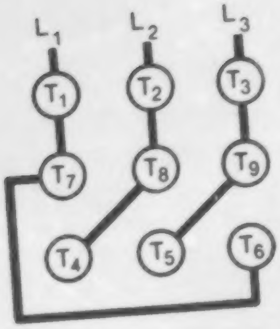

L1
T1
T9
T4
T6
T7
T8
T5
L3
T3
T2
L2

_____d.

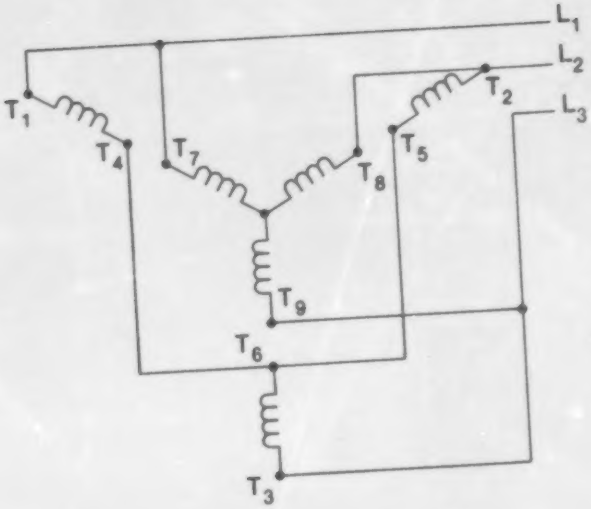

L1
L2
L3
T1
T2
T3
T7
T8
T9
T4
T5
T6

TEST

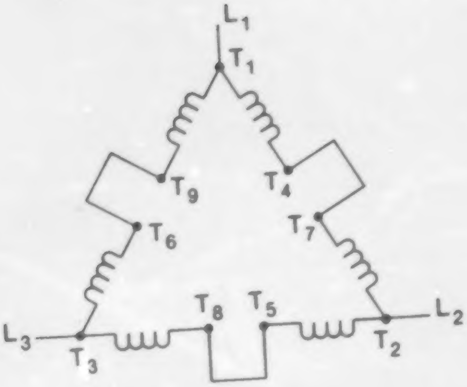
_____e.


L1
L2
L3
T1
T2
T3
T7
T8
T9
T4
T5
T6

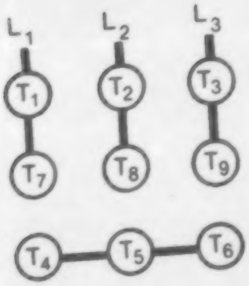
_____f.


L1
L2
L3
T1
T4
T7
T8
T2
T5
T9
T6
T3

_____g.


L1
T1
T9
T4
T6
T7
L3
T3
T8
T5
T2
L2

_____h.


L1
L2
L3
T1
T2
T3
T7
T8
T9
T4
T5
T6

TEST

(NOTE: Test questions 9-11 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Match windings to their proper configurations and voltages.
10. Make proper connections on three-phase motors.
11. Demonstrate the ability to
    a. Test a three-phase delta-connected motor.
    b. Test a three-phase wye-connected motor.
    c. Wire a motor for dual voltages.

THREE-PHASE MOTORS
UNIT V

ANSWERS TO TEST

1.

a.	6	h.	13
b.	9	i.	11
c.	3	j.	14
d.	5	k.	2
e.	12	l.	7
f.	1	m.	4
g.	10	n.	8

2. a. Synchronous
   b. Squirrel-cage rotor
   c. Wound rotor

3. a, b, d, f, h

4. b

5.

a.	SQ	h.	WR
b.	SYN	i.	SQ
c.	SYN	j.	SYN
d.	WR	k.	SYN
e.	WR	l.	SQ, WR
f.	SYN	m.	WR
g.	SQ		

ANSWERS TO TEST

6. Description should include the following

   Rotation of any three-phase motor may be reversed by switching any two of the line-voltage leads

7. a. 230-volt three-phase delta
   b. 480-volt three-phase delta
   c. 208-volt three-phase wye
   d. 480-volt three-phase wye

8. a. 8 or 6
   b. 2
   c. 4
   d. 6 or 8
   e. 1
   f. 7
   g. 5
   h. 3

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor

CONTACTORS AND MOTOR STARTERS
UNIT VI

UNIT OBJECTIVE

After completing this unit, the student should be able to distinguish between contactors and motor starters and use them properly in motor controls. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with contactors and motor starters to their correct definitions.
2. Name types of contactors.
3. Label the parts of a manual contactor.
4. Name types of magnetic-contactor assemblies.
5. Name electrical devices and circuits controlled by magnetic contactors.
6. Name types of motor starters.
7. Label types of magnetic motor starters and their parts.
8. Name uses of magnetic motor starters.
9. Distinguish between parts in magnetic contactors and parts in magnetic motor starters.
10. State reasons a contactor cannot be used to control a motor.
11. State purposes of a coil assembly.
12. Label parts of a coil assembly.
13. Answer questions about uses of contactors and motor starters.
14. Demonstrate the ability to
    - a. Disassemble, replace movable contacts, and reassemble a contactor or motor starter.
    - b. Replace a magnetic coil in a magnetic motor starter or contactor.
    - c. Clean and inspect armature and shading coil of coil assembly.

CONTACTORS AND MOTOR STARTERS
UNIT VI

SUGGESTED ACTIVITIES

I. Suggested activities

   A. Make transparencies.

   B. Collect contactors, motor starters, and coil assemblies to supplement classroom discussions.

   C. Provide students with objective sheet.

   D. Discuss unit and specific objectives. State need for knowledge in each area.

   E. Provide students with information, assignment, and job sheets.

   F. Discuss terms and definitions, using Information Sheet, Section I, and actual starters and contactors. Describe the functions of the parts and show their location in each device.

   G. Point out parts of a manual contactor, using Information Sheet, Section III, and Transparency #1.

   H. Help students identify types of magnetic contactors and name devices and circuits controlled by magnetic contactors by using Information Sheet, Sections IV and V, Transparency #2, and Job Sheet #1. Point out the differences in their construction. Point out that most contactors used today are bell crank-type.

   I. Use Information Sheet, Section VII, to discuss the various types of motor starters, pointing out similarities and differences in the parts of each. Also explain the uses of magnetic motor starters, using Information Sheet, Section VIII.

   J. Use Information Sheet, Section IX, and Assignment Sheets #1 and #2 to emphasize the importance of a technician's being able to recognize the differences between contactors and motor starters.

   K. Discuss parts of a coil assembly, using Information Sheet, Section XII, and Transparency #3. Explain the purpose of the parts and their construction. Use Job Sheets #2 and #3 to reinforce the parts of a coil assembly.

   L. Give test.

   M. Reteach and retest if necessary.

SUGGESTED ACTIVITIES

II. Instructional materials

- A. Objective sheet
- B. Suggested activities
- C. Information sheet
- D. Transparency masters
  1. TM #1 — Parts of a Manual Contactor
  2. TM #2 — Types of Magnetic-Contactor Assemblies
  3. TM #3 — Parts of a Coil Assembly
- E. Assignment sheets
  1. Assignment Sheet #1 — Answer Questions About Uses of Contactors and Motor Starters
  2. Assignment Sheet #2 — Distinguish Between Motor Starters and Contactors
- F. Answers to assignment sheets
- G. Job sheets
  1. Job Sheet #1 — Disassemble, Replace Movable Contacts, and Reassemble a Contactor or Motor Starter
  2. Job Sheet #2 — Replace a Magnetic Coil in a Magnetic Motor Starter or Contactor
  3. Job Sheet #3 — Clean and Inspect Armature and Shading Coil of Coil Assembly
- H. Test
- I. Answers to test

III. Unit reference — Rockis, Gary, and Glen Mazur. *Electrical Motor Controls.* American Technical Publishers, Inc.: Alsip, Illinois, 1982.

CONTACTORS AND MOTOR STARTERS
UNIT VI

INFORMATION SHEET

I. Terms and definitions

A. Contactor — Device used to make and break an electrical power circuit

B. Motor starter — Device used to make and break a motor's power circuit

C. Reversing starter — Starter used to change direction of rotation of a motor

D. Coil — Electromagnet used to actuate a contactor or motor starter

E. Coil assembly — Coil, armature, magnetic assembly, and shading coil

F. Holding contact — Auxiliary contact in the normally open position; used to hold power for the coil

G. Line terminals — Top terminals on contactor or motor starter for connection of incoming power

H. Load terminals — Bottom terminals on contactor or motor starter for connection of outgoing power to load

I. Coil terminals — Terminals designed to pass power from a control circuit to a magnetic coil

J. Power contacts — Contacts that switch the main power to load

K. Thermal overload (heater) — Device used to sense current draw in a circuit and open a control circuit when rating is exceeded

L. Arc chute — Partition between contacts to reduce electrical arcing

M. Eddy current — Magnetic current induced in metal; produces unwanted heat

N. Lamination — Many layers pressed closely together

O. Armature — Portion of coil assembly moved by magnetism

P. Shading coil — Single turn of conducting material mounted on the armature face to produce out-of-phase magnetic force

Q. Coil inrush — Amount of current draw needed to start closing process of solenoid

INFORMATION SHEET

R. Solenoid — Frame, plunger, and coil; changes electrical to mechanical power

S. Poles — Separate sets of switching contacts

EXAMPLE: Three-phase has three poles.

T. Saddle clamp — Device used to attach a wire to a terminal

U. Magnetic assembly — Device made of metal laminations and shading coils that provides magnetic lines of force to attract the armature

V. Reset button — Device used to reset the overload contacts after they have operated

W. Overload contact — Device used to interrupt control power in the event of an overload

II. Types of contactors

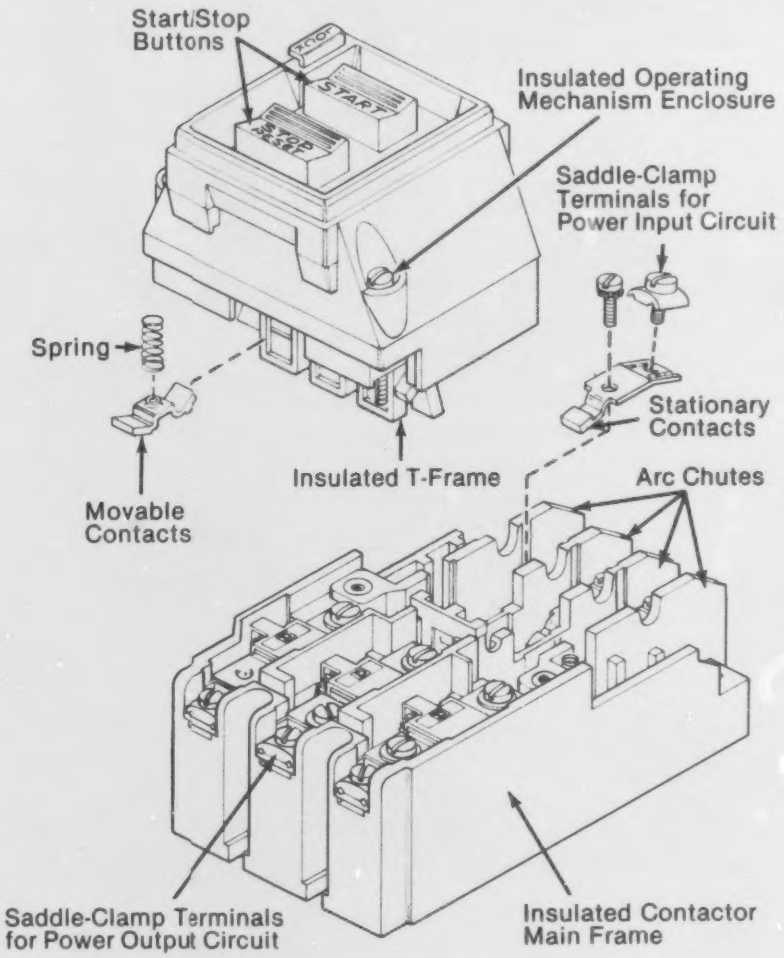
A. Manual

B. Magnetic

INFORMATION SHEET

III. Parts of a manual contactor (Figure 1; Transparency #1)

FIGURE 1


Start/Stop Buttons
STOP RESET
START
Insulated Operating Mechanism Enclosure
Saddle-Clamp Terminals for Power Input Circuit
Spring
Stationary Contacts
Insulated T-Frame
Arc Chutes
Movable Contacts
Saddle-Clamp Terminals for Power Output Circuit
Insulated Contactor Main Frame

Courtesy of Square D Company.

IV. Types of magnetic-contactor assemblies (Transparency #2)

A. Clapper

B. Horizontal action

C. Bell crank

INFORMATION SHEET

V. Electrical devices and circuits controlled by magnetic contactors

   A. Lighting loads

   B. Heaters

   C. Transformers

   D. Capacitors

   E. Power circuits

VI. Types of motor starters

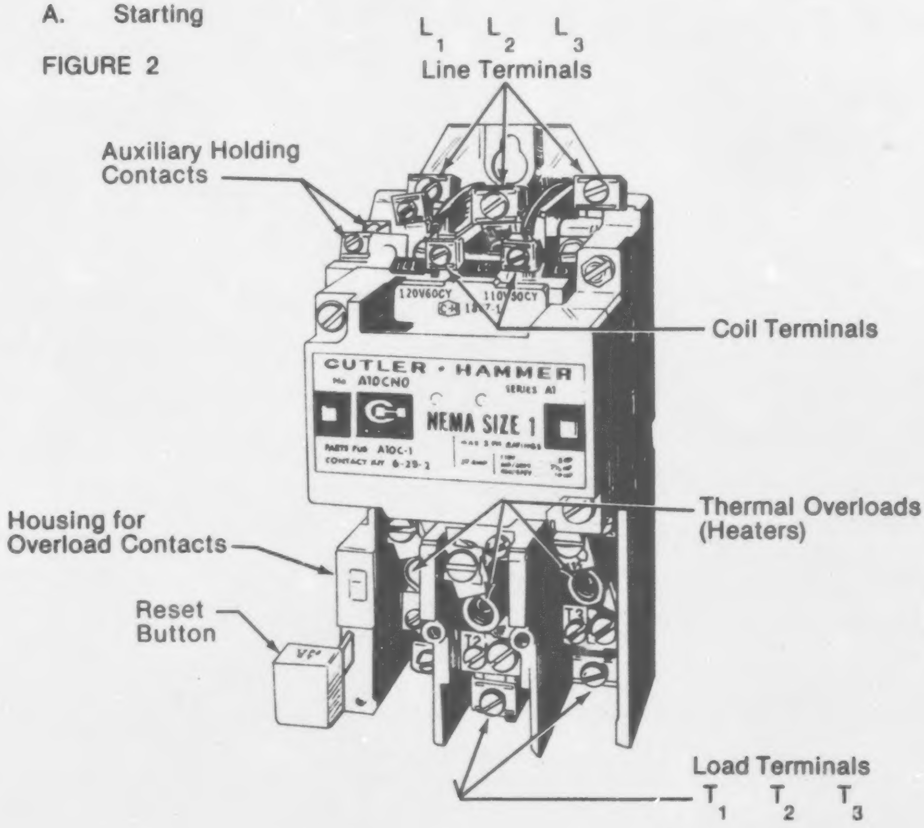
   A. Manual

   B. Magnetic

VII. Types of magnetic motor starters and their parts (Figures 2-4)

   A. Starting

FIGURE 2

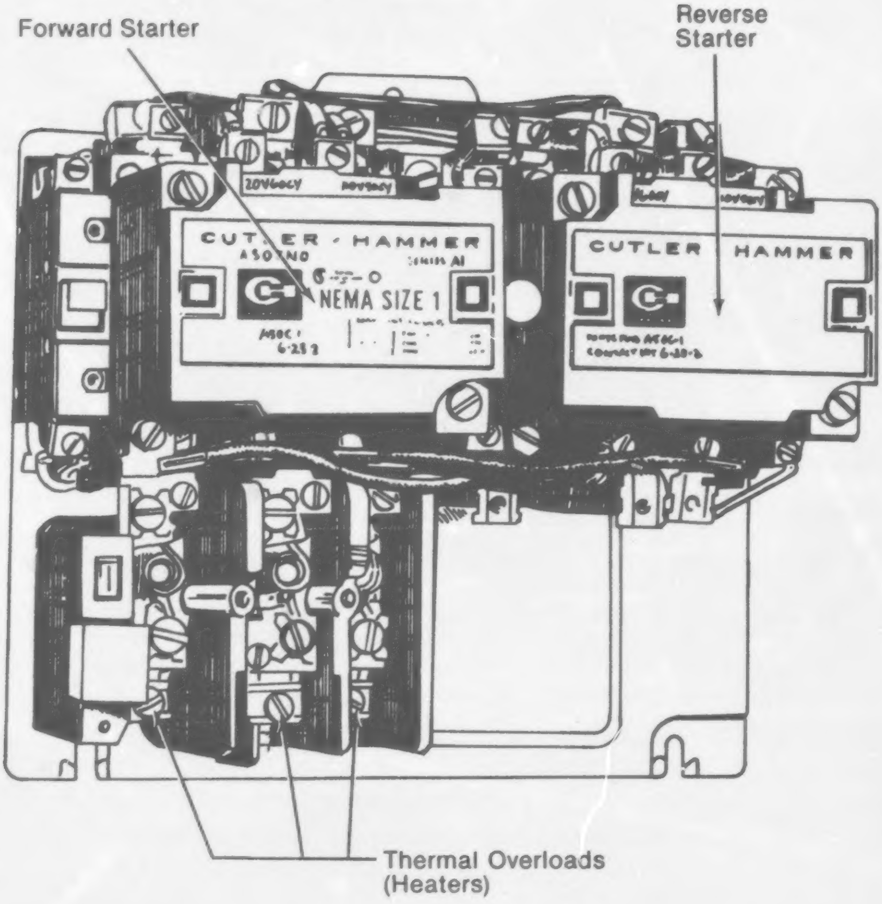

L_1 L_2 L_3
Line Terminals
Auxiliary Holding Contacts
120V60CY
110V50CY
Coil Terminals
CUTLER • HAMMER
No A10CN0
SERIES A1
NEMA SIZE 1
PARTS FOR A10C-1
CONTACT KIT 6-29-2
Thermal Overloads (Heaters)
Housing for Overload Contacts
Reset Button
Load Terminals
T_1 T_2 T_3

Adapted with permission of Eaton Corp., Cutler-Hammer Products.

INFORMATION SHEET

B. Reversing

FIGURE 3


Forward Starter
Reverse Starter
CUTLER - HAMMER
NEMA SIZE 1
CUTLER HAMMER
Thermal Overloads (Heaters)

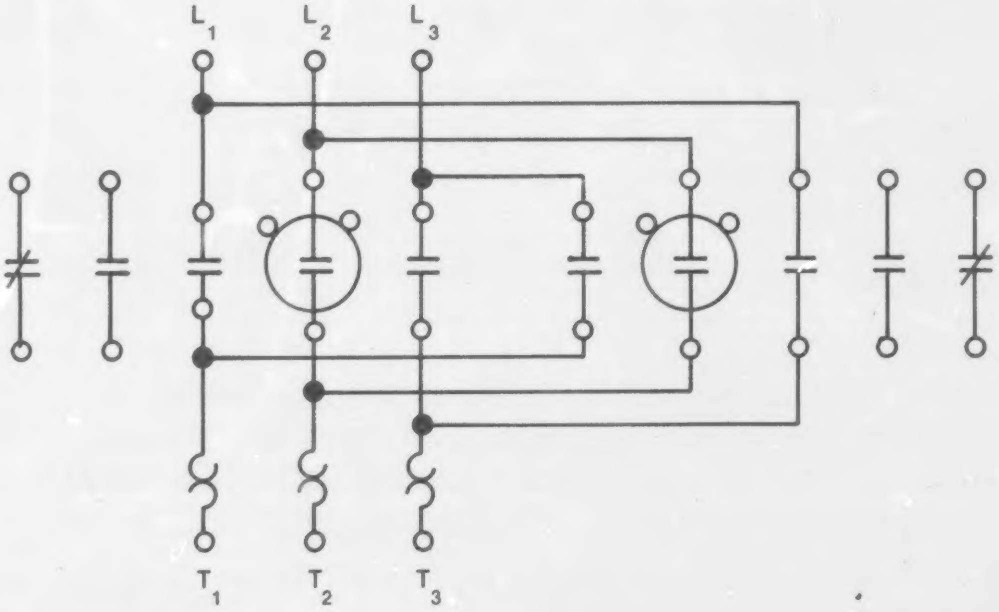
Adapted with permission of Eaton Corp., Cutler-Hammer Products.

INFORMATION SHEET

(NOTE: Reversing any two phases will change rotation of motor. L1 and L3 are reversed in Figure 4.)

EXAMPLE:

FIGURE 4



Adapted with permission of Eaton Corp., Cutler-Hammer Products.

INFORMATION SHEET

VIII. Uses of magnetic motor starters

- A. Starting motors
- B. Reversing motors
- C. Braking motors to stop
- D. Controlling speed of motors

IX. Comparison of parts in magnetic contactors and parts in magnetic motor starters (Table 1; Assignment Sheets #1 and #2)

(NOTE: Motor starters are contactors with overload protection for the motor.)

TABLE 1

Parts	**Contactors**	**Motor Starters**
Line terminals	Yes	Yes
Power contacts	Yes	Yes
Load terminals	Yes	Yes
Holding contacts	Yes	Yes
Coil	Yes	Yes
Thermal overloads (heaters)	No	Yes
Reset button	No	Yes
Overload contact	No	Yes

X. Reasons a contactor cannot be used to control a motor

- A. Contactor does not provide running overload protection for motor
- B. Contactor is not designed for high inrush current for motor starting
- C. Contactor does not contain a set of overload contacts

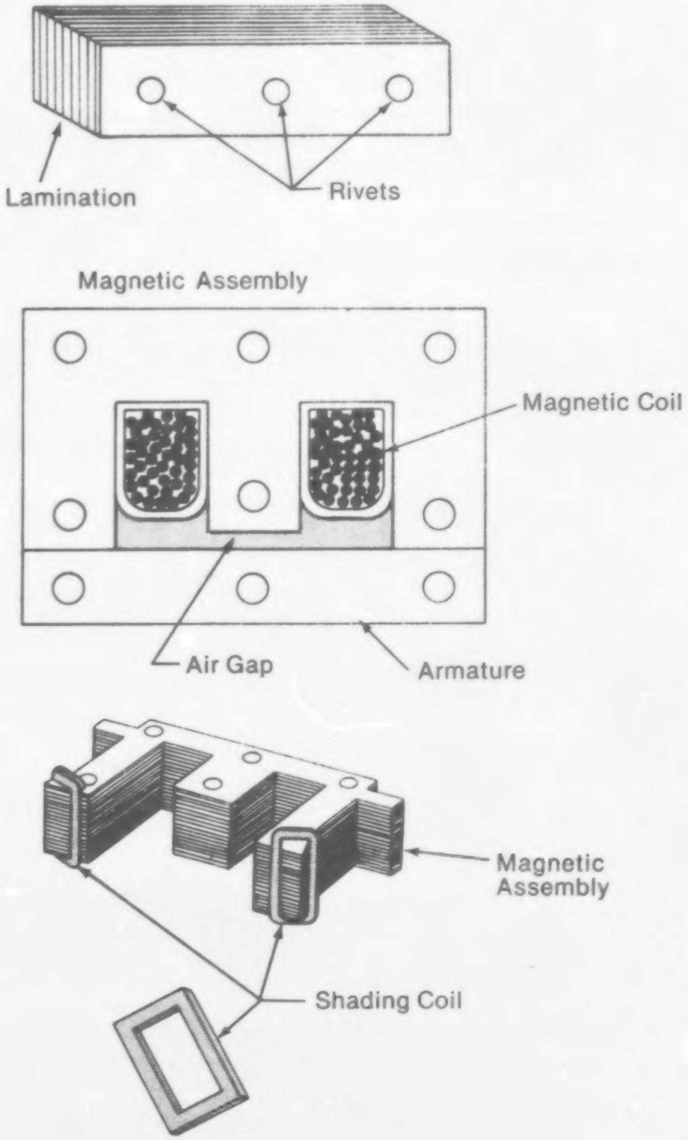
XI. Purposes of a coil assembly

- A. Changes electrical signal to magnetic signal
- B. Activates mechanical portion of motor starter

INFORMATION SHEET

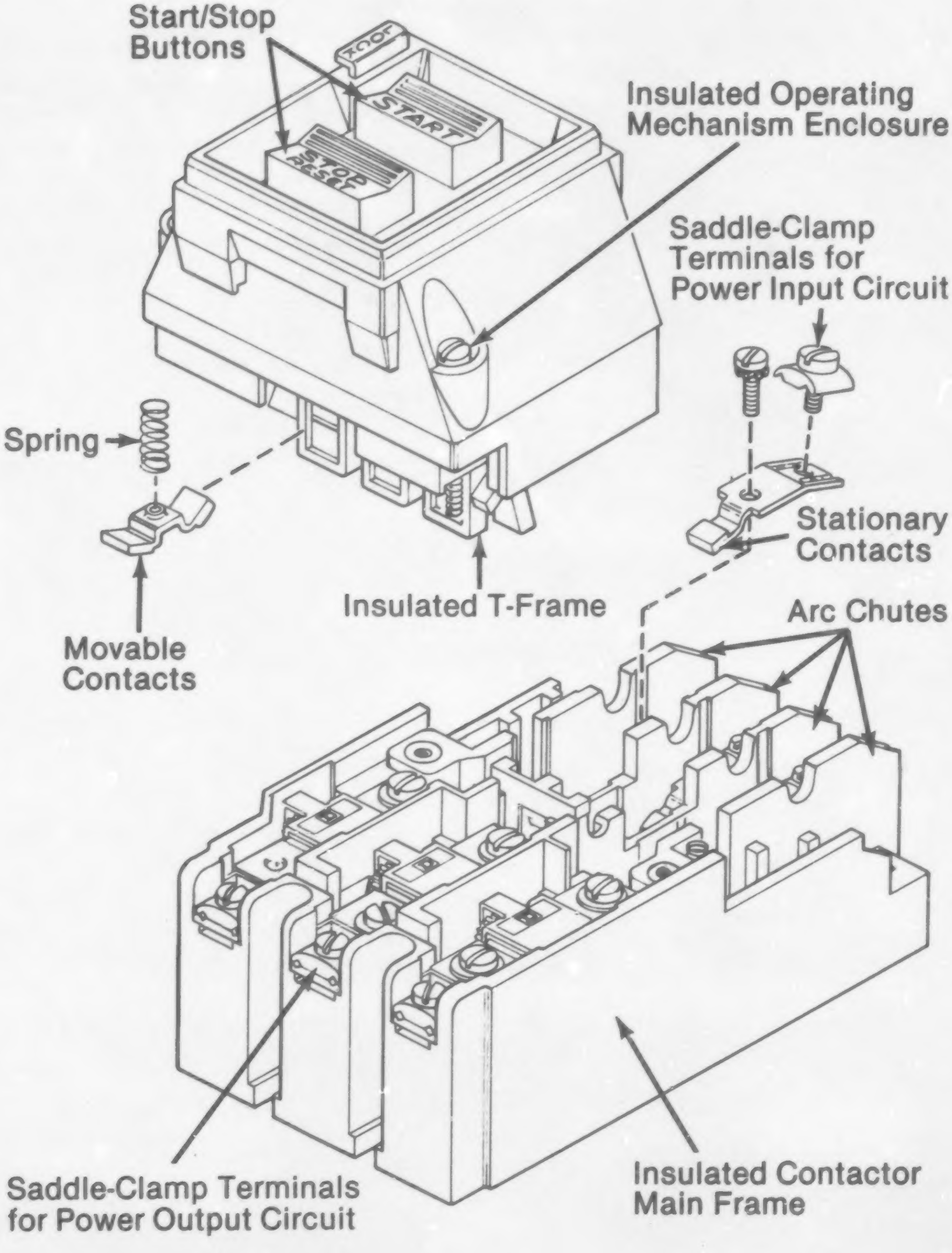
XII. Parts of a coil assembly (Figure 5; Transparency #3)

FIGURE 5


Lamination
Rivets
Magnetic Assembly
Magnetic Coil
Air Gap
Armature
Magnetic Assembly
Shading Coil

Adapted with permission of American Technical Publishers, Inc., Alsip, Illinois.

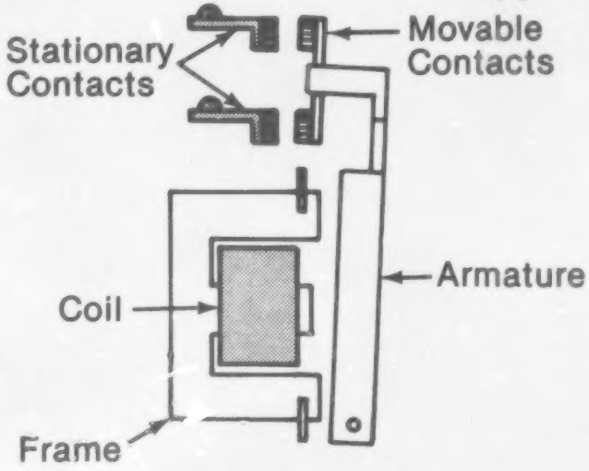
Parts of a Manual Contactor

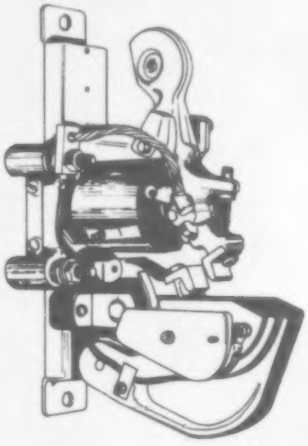

Start/Stop Buttons
START
STOP RESET
Insulated Operating Mechanism Enclosure
Saddle-Clamp Terminals for Power Input Circuit
Spring
Stationary Contacts
Insulated T-Frame
Arc Chutes
Movable Contacts
Saddle-Clamp Terminals for Power Output Circuit
Insulated Contactor Main Frame

Courtesy of Square D Company.

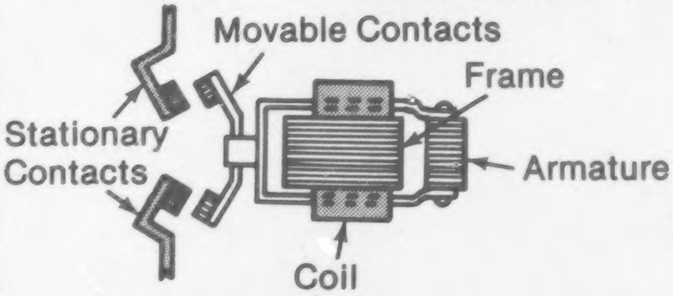
Types of Magnetic-Contactor Assemblies

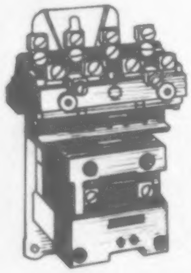
Clapper


Stationary Contacts
Movable Contacts
Armature
Coil
Frame

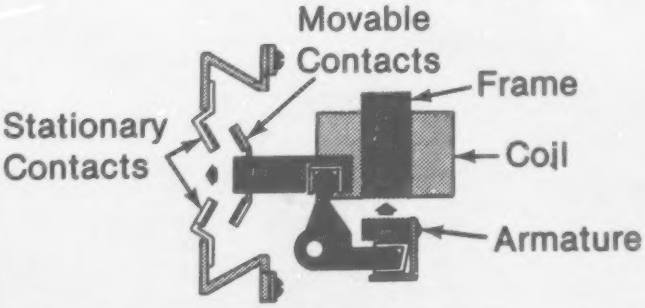


Horizontal Action


Movable Contacts
Frame
Stationary Contacts
Armature
Coil

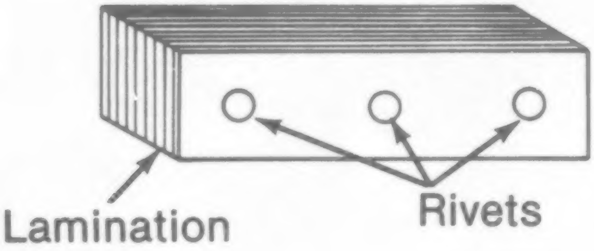


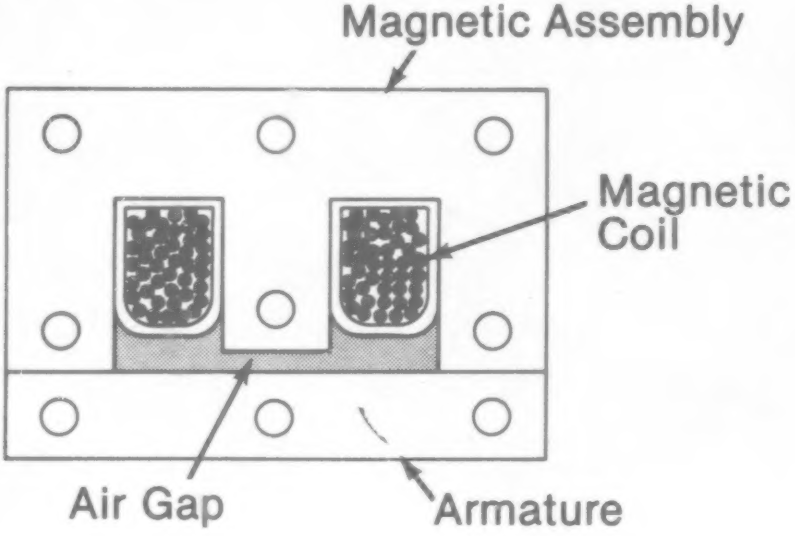
Bell Crank

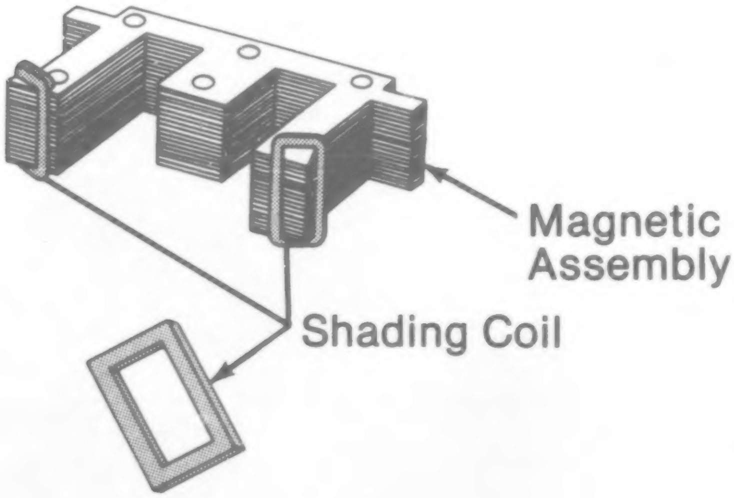

Movable Contacts
Frame
Stationary Contacts
Coil
Armature

Adapted with permission of Eaton Corp., Cutler-Hammer Products; the Allen-Bradley Company, Milwaukee, Wisconsin, and courtesy of Square D Company.

Parts of a Coil Assembly


Lamination
Rivets


Magnetic Assembly
Magnetic Coil
Air Gap
Armature


Magnetic Assembly
Shading Coil

Adapted with permission of American Technical Publishers, Inc., Alsip, Illinois.

CONTACTORS AND MOTOR STARTERS
UNIT VI

ASSIGNMENT SHEET #1 — ANSWER QUESTIONS ABOUT USES OF CONTACTORS AND MOTOR STARTERS

NAME ______________________________ SCORE ______________

An electrical technician must be able to select a motor starter or contactor according to its correct use. Contactors are used to make and break an electrical power circuit. Motor starters are used to make and break a motor's power circuit.

Complete each of the following questions about motor starters and contactors and their uses.

A. Which of the following lists contains contactor parts and which contains motor starter parts? Write "contactor" or "motor starter" in the blank above the correct column.

1. ______________________	2. ______________________
Line terminals	Line terminals
Load terminals	Load terminals
Power contacts	Coil
Coil	Holding contacts
Holding contacts	Power contacts
Overload contact	
Reset button	
Thermal overloads (heaters)	

B. Name five uses of magnetic contactors.

1. ____
2. ____
3. ____
4. ____
5. ____

C. List four uses of magnetic motor starters.

1. ____
2. ____
3. ____
4. ____

ASSIGNMENT SHEET #1

D. State three reasons why a contactor cannot be used to control a motor.

1. ____
____

2. ____
____

3. ____
____

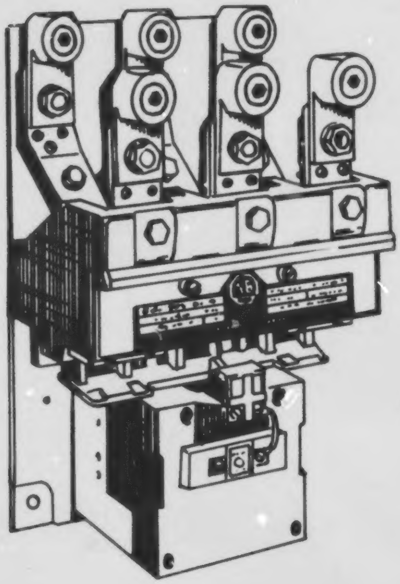
CONTACTORS AND MOTOR STARTERS
UNIT VI

ASSIGNMENT SHEET #2 — DISTINGUISH BETWEEN MOTOR STARTERS AND CONTACTORS

NAME ______________________________ SCORE ______________

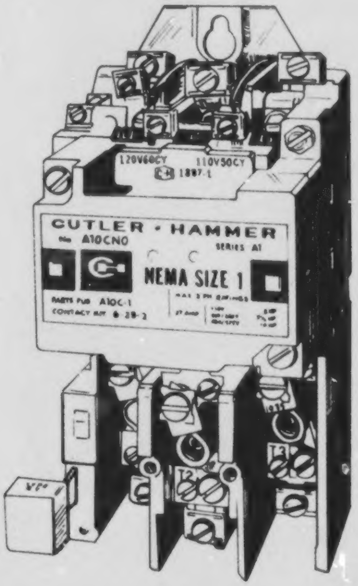
When servicing existing equipment, a technician must be able to identify at a glance a motor starter or a contactor. Contactors never have thermal overloads (heaters), reset buttons, or overload contacts.

Look at each of the following pictures. Label each "contactor" or "motor starter."



A. ______________________________

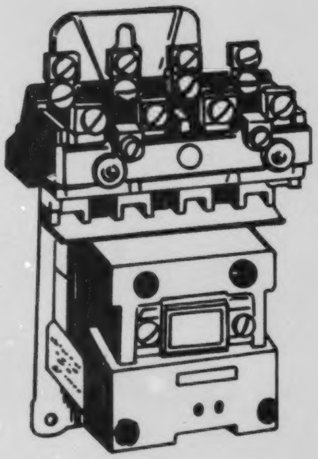
Adapted with permission of the Allen-Bradley Company, Milwaukee, Wisconsin.


120V60CY
110V50CY
CUTLER · HAMMER
A10CNO
SERIES A1
NEMA SIZE 1

B. ______________________________

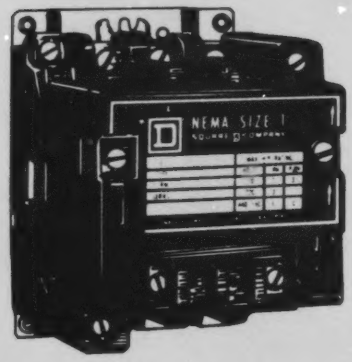
Adapted with permission of Eaton Corp., Cutler-Hammer Products.

ASSIGNMENT SHEET #2



C. ______________________________

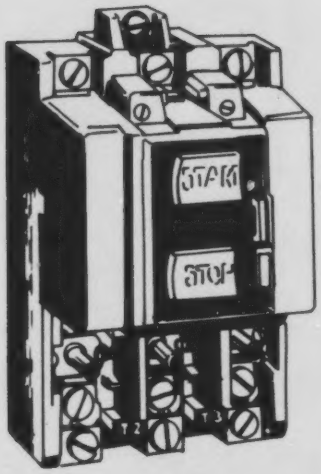
Adapted with permission of the Allen-Bradley Company, Milwaukee, Wisconsin.


NEMA SIZE 1
SQUARE D COMPANY

D. ______________________________

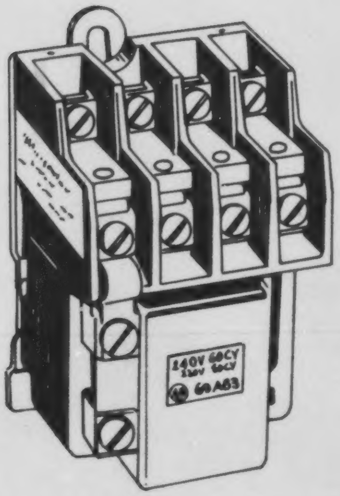
Courtesy of Square D Company.

ASSIGNMENT SHEET #2


START
STOP
T2
T3

E. ______________________________

Adapted with permission of Eaton Corp., Cutler-Hammer Products.



F. ______________________________

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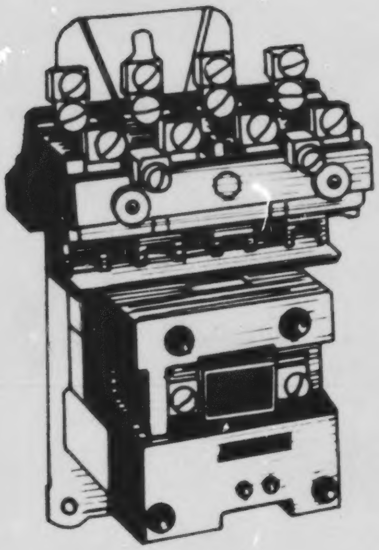
ASSIGNMENT SHEET #2



G. ____________________

Adapted with permission of the Allen-Bradley Company, Milwaukee, Wisconsin.

ASSIGNMENT SHEET #2

H. Which items did you recognize as being contactors? ______________________________

Explain why you selected these items as contactors.

____

____

____

I. Which items did you select as being motor starters? ______________________________

Explain why you selected these items as motor starters.

____

____

____

CONTACTORS AND MOTOR STARTERS
UNIT VI

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1. Motor starter

2. Contactor

B. 1. Lighting loads

2. Heaters

3. Transformers

4. Capacitors

5. Power circuits

C. 1. Starting motors

2. Reversing motors

3. Braking motors to stop

4. Controlling speed of motors

D. 1. Contactor does not provide running overload protection for motor

2. Contactor is not designed for high inrush current for motor starting

3. Contactor does not contain a set of overload contacts

Assignment Sheet #2

A. Contactor

B. Motor starter

C. Contactor

D. Contactor

E. Motor starter

ANSWERS TO ASSIGNMENT SHEETS

F. Contactor

G. Contactor

H. A, C, D, F, G; contactors do not have thermal overloads (heaters), reset button, or overload contacts

I. B, E; motor starters have thermal overloads (heaters), reset button, and overload contacts

CONTACTORS AND MOTOR STARTERS
UNIT VI

JOB SHEET #1 — DISASSEMBLE, REPLACE MOVABLE CONTACTS, AND REASSEMBLE A CONTACTOR OR MOTOR STARTER

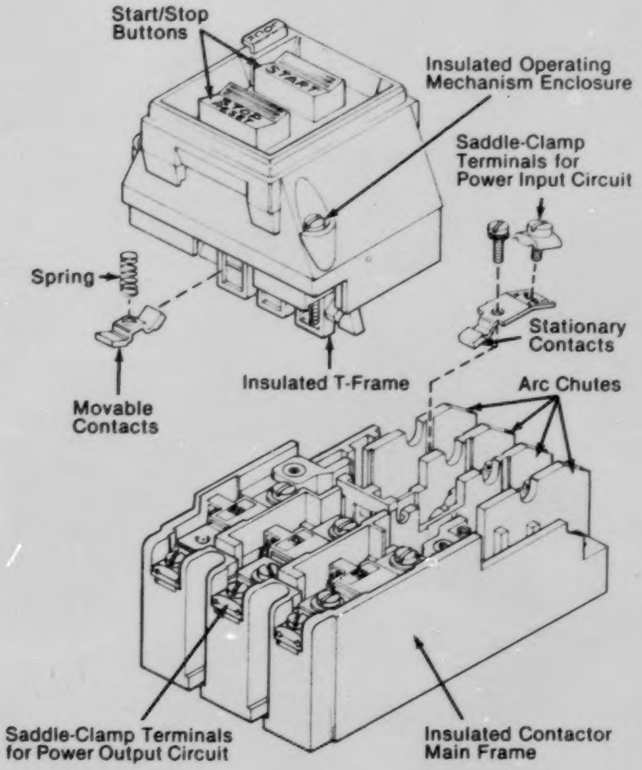
I. Equipment and materials

- A. Contactor or motor starter
- B. Screwdriver
- C. Needle-nosed pliers

II. Procedure (Figure 6)

(NOTE: Figure 6 illustrates a manual contactor; however, contacts are the same on manual and magnetic contactors and motor starters.)

FIGURE 6


Start/Stop Buttons
STOP
START
STOP RESET
Insulated Operating Mechanism Enclosure
Saddle-Clamp Terminals for Power Input Circuit
Spring
Stationary Contacts
Insulated T-Frame
Arc Chutes
Movable Contacts
Saddle-Clamp Terminals for Power Output Circuit
Insulated Contactor Main Frame

Courtesy of Square D Company.

JOB SHEET #1

A. Remove screws holding insulated operating mechanism enclosure to insulated contactor main frame

B. Gently pull operating mechanism enclosure from main frame

C. Locate movable contacts; remove them from holder

(NOTE: Take care not to allow the small spring on top of the contact to jump out and become lost.)

D. Replace movable contacts and springs

E. Reassemble contactor or motor starter

(NOTE: Have instructor check your reassembled contactor or motor starter.)

F. Clean work area; put away equipment and materials

CONTACTORS AND MOTOR STARTERS
UNIT VI

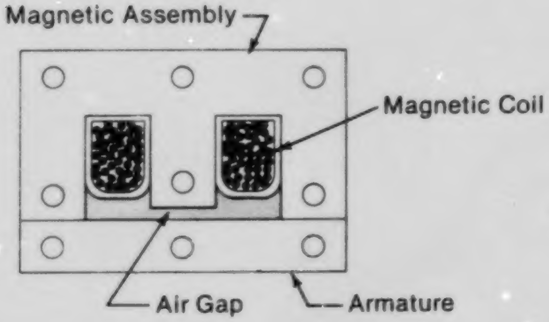
JOB SHEET #2 — REPLACE A MAGNETIC COIL IN A MAGNETIC MOTOR STARTER OR CONTACTOR

I. Equipment and materials

- A. Magnetic motor starter or contactor
- B. Screwdriver
- C. New magnetic coil

II. Procedure (Figure 7)

FIGURE 7



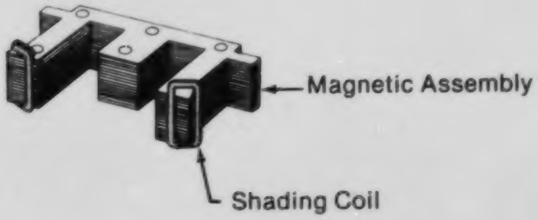
Used with permission of American Technical Publishers, Inc., Alsip, Illinois.

- A. Remove screws from coil cover
- B. Loosen screws on coil terminals and remove coil wires
- C. Remove coil cover and coil assembly
- D. Disassemble armature and coil assembly

JOB SHEET #2

E. Replace coil and reassemble coil assembly (Figure 8)

FIGURE 8



Used with permission of American Technical Publishers, Inc., Alsip, Illinois.

F. Replace coil assembly in contactor or motor starter

G. Replace coil cover

H. Tighten coil cover screws

I. Hook coil wires to coil terminals

(NOTE: Have instructor inspect contactor or motor starter.)

J. Clean work area; put away equipment and materials

CONTACTORS AND MOTOR STARTERS
UNIT VI

JOB SHEET #3 — CLEAN AND INSPECT ARMATURE AND SHADING COIL OF COIL ASSEMBLY

I. Equipment and materials

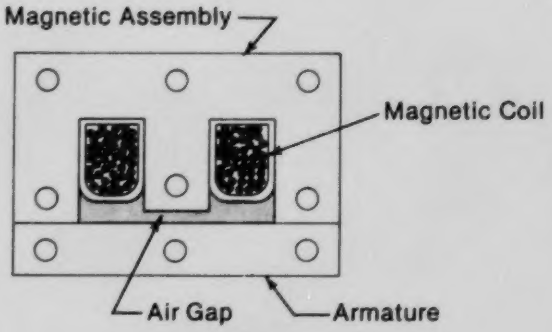
A. Magnetic contactor or motor starter

B. Screwdriver

C. Wire brush

II. Procedure (Figure 9)

FIGURE 9



Used with permission of American Technical Publishers, Inc., Alsip, Illinois.

A. Remove screws from coil cover

B. Loosen screws on coil terminals, and remove coil wires

C. Remove coil cover and coil assembly

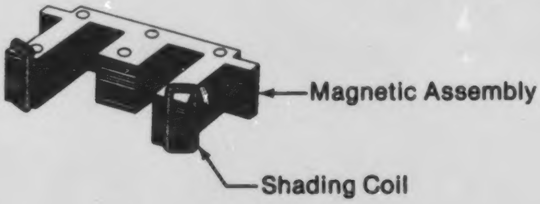
D. Disassemble armature and coil assembly

E. Clean armature with wire brush

JOB SHEET #3

F. Check shading coil to see that it is secure (Figure 10)

FIGURE 10



Used with permission of American Technical Publishers, Inc., Alsip, Illinois.

G. Reassemble coil assembly

H. Replace coil assembly in contactor or motor starter

I. Replace coil cover

J. Tighten coil cover screws

K. Hook coil wires to coil terminals

(NOTE: Have instructor inspect contactor or motor starter.)

L. Clean work area; put away equipment and materials

CONTACTORS AND MOTOR STARTERS
UNIT VI

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with contactors and motor starters to their correct definitions. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

_____a. Contacts that switch the main power to load

_____b. Separate sets of switching contacts

_____c. Many layers pressed closely together

_____d. Electromagnet used to actuate a contactor or motor starter

_____e. Bottom terminals on contactor or motor starter for connection of outgoing power to load

_____f. Device used to make and break an electrical power circuit

_____g. Coil, armature, magnetic assembly, and shading coil

_____h. Partition between contacts to reduce electrical arcing

_____i. Device used to make and break a motor's power circuit

_____j. Auxiliary contact in the normally open position; used to hold power for the coil

_____k. Top terminals on contactor or motor starter for connection of incoming power

_____l. Device used to attach a wire to a terminal

_____m. Single turn of conducting material mounted on the armature face to produce out-of-phase magnetic force

_____n. Device used to sense current draw in a circuit and open a control circuit when rating is exceeded

_____o. Portion of coil assembly moved by magnetism

1. Contactor
2. Motor starter
3. Coil
4. Holding contact
5. Line terminals
6. Load terminals
7. Coil assembly
8. Power contacts
9. Thermal overload (heater)
10. Arc chute
11. Poles
12. Lamination
13. Armature
14. Shading coil
15. Saddle clamp

TEST

______p. Amount of current draw needed to start closing process of solenoid

______q. Magnetic current induced in metal; produces unwanted heat

______r. Starter used to change direction of rotation of a motor

______s. Terminals designed to pass power from a control circuit to a magnetic coil

______t. Frame, plunger, and coil; changes electrical to mechanical power

______u. Device used to reset the overload contacts after they have operated

______v. Device used to interrupt control power in the event of an overload

______w. Device made of metal laminations and shading coils that provides magnetic lines of force to attract the armature

16. Coil inrush
17. Solenoid
18. Reversing starter
19. Coil terminals
20. Eddy current
21. Reset button
22. Magnetic assembly
23. Overload contact

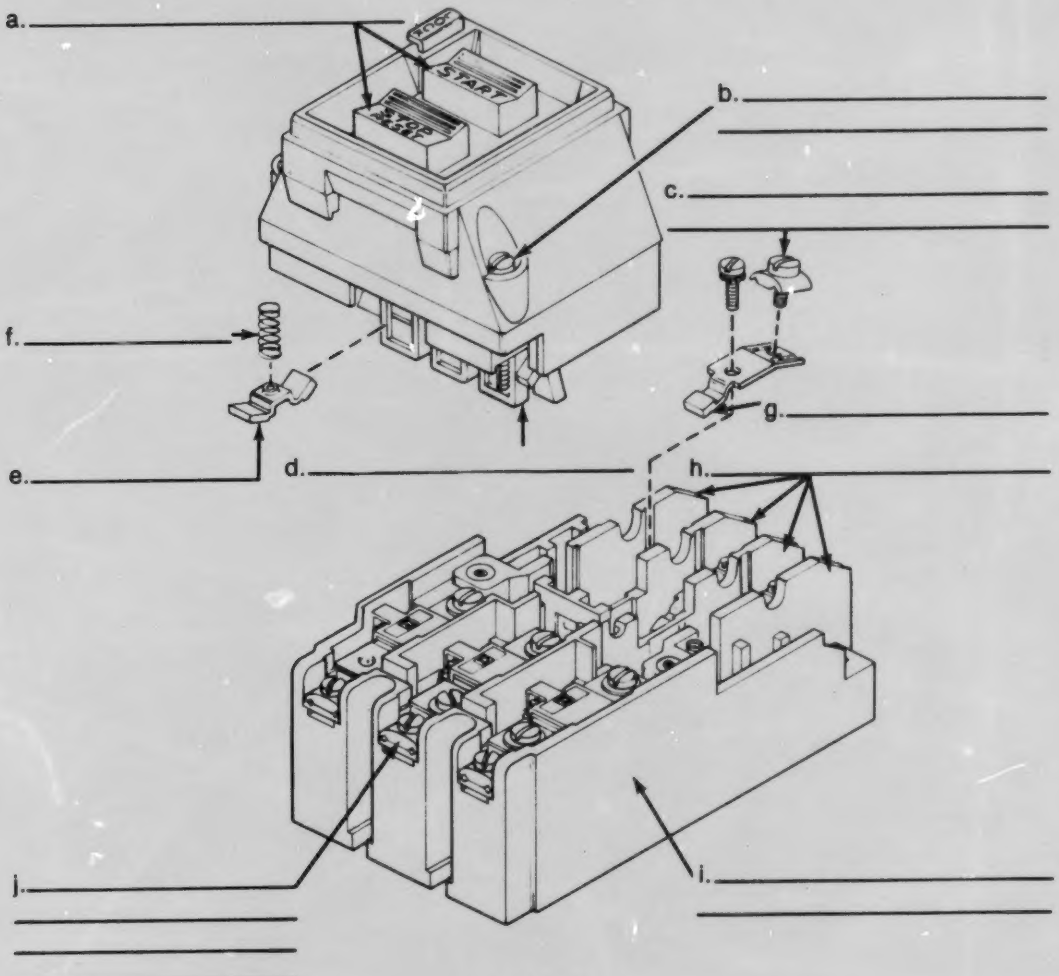
2. Name types of contactors.

a. ______________________________

b. ______________________________

TEST

3. Label the parts of the manual contactor illustrated below.


a.
START
STOP
RESET
b.
c.
f.
g.
e.
d.
h.
i.
j.

TEST

4. Name types of magnetic-contactor assemblies.

a. ______________________________

b. ______________________________

c. ______________________________

5. Name three electrical devices and circuits controlled by magnetic contactors.

a. ______________________________

b. ______________________________

c. ______________________________

6. Name types of motor starters.

a. ______________________________

b. ______________________________

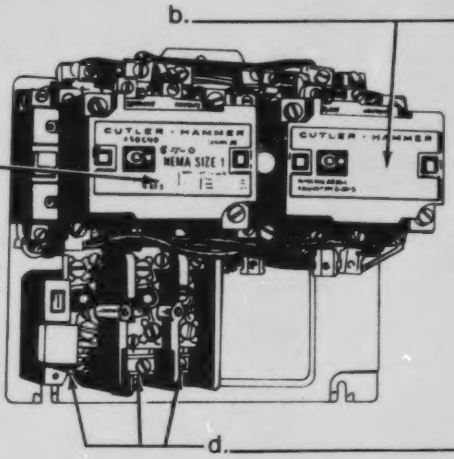
TEST

7. Label the following types of magnetic motor starters and their parts.

a. *Type:* ____________________

b. ____________________

c. ____________________

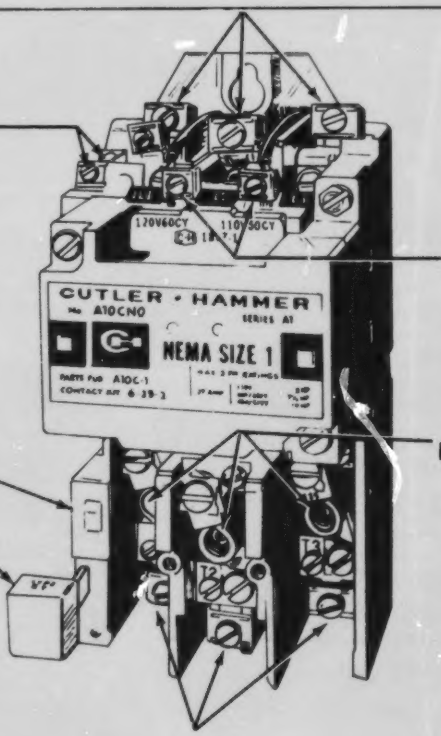

CUTLER · HAMMER
NEMA SIZE 1
CUTLER · HAMMER

d. ____________________

e. *Type:* ____________________

f. ____________________

g. ____________________


120V60CY
110V50CY
CUTLER · HAMMER
No A10CNO
SERIES A1
NEMA SIZE 1
PARTS No A10C-1
CONTACT KIT 6-39-2

l. ____________________

k. ____________________

h. ____________________
____

i. ____________________
____

j. ____________________

TEST

8. Name uses of magnetic motor starters.

a. ________________________

b. ________________________

c. ________________________

d. ________________________

9. Distinguish between parts in magnetic contactors and parts in magnetic motor starters by completing the chart below.

Parts	Contactors	Motor Starters
Holding contacts		
Reset button		
Coil		
Overload contact		
Thermal overloads (heaters)		
Load terminals		
Power contacts		
Line terminals		

10. State reasons a contactor cannot be used to control a motor.

a. ________________________

____

b. ________________________

____

c. ________________________

____

11. State purposes of a coil assembly.

a. ________________________

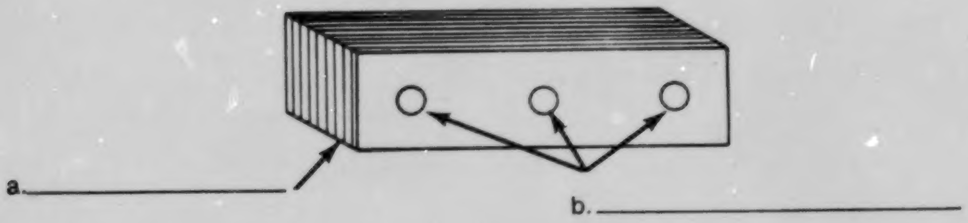
____

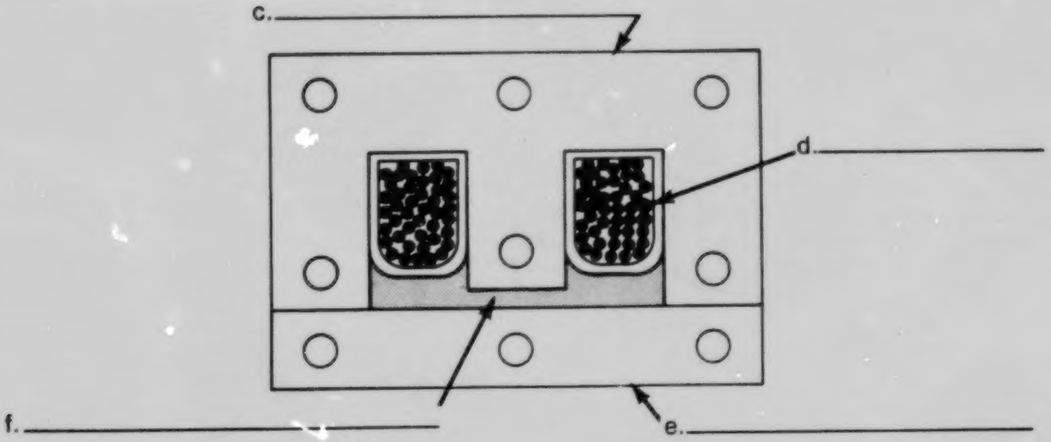
b. ________________________

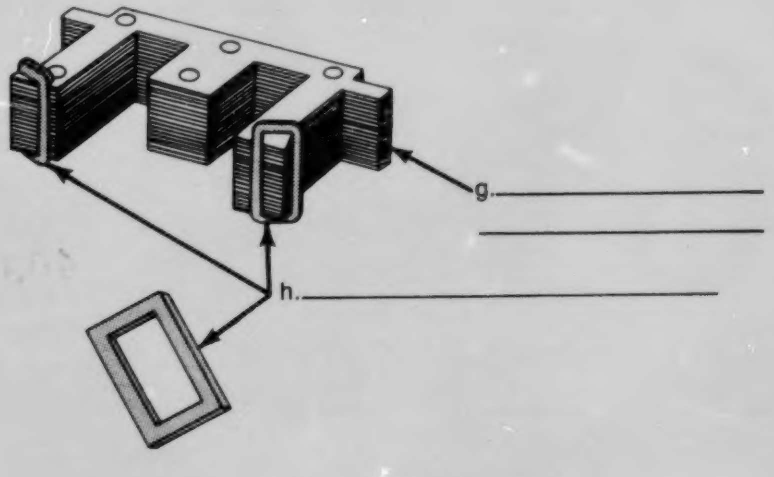
____

TEST

12. Label parts of the coil assembly illustrated below.







TEST

(NOTE: Test questions 13 and 14 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with the instructor.)

13. Answer questions about uses of contactors and motor starters.

14. Demonstrate the ability to

    a. Disassemble, replace movable contacts, and reassemble a contactor or motor starter.

    b. Replace a magnetic coil in a magnetic motor starter or contactor.

    c. Clean and inspect armature and shading coil of coil assembly.

CONTACTORS AND MOTOR STARTERS
UNIT VI

ANSWERS TO TEST

1.

a.	8	g.	7	m.	14	s.	19
b.	11	h.	10	n.	9	t.	17
c.	12	i.	2	o.	13	u.	21
d.	3	j.	4	p.	16	v.	23
e.	6	k.	5	q.	20	w.	22
f.	1	l.	15	r.	18		

2. a. Manual
   b. Magnetic

3. a. Start/stop buttons
   b. Insulated operating mechanism enclosure
   c. Saddle-clamp terminals for power input circuit
   d. Insulated T-frame
   e. Movable contacts
   f. Spring
   g. Stationary contacts
   h. Arc chutes
   i. Insulated contactor main frame
   j. Saddle-clamp terminals for power output circuit

4. a. Clapper
   b. Horizontal action
   c. Bell crank

ANSWERS TO TEST

5. Answer should include any three of the following
   - a. Lighting loads
   - b. Heaters
   - c. Transformers
   - d. Capacitors
   - e. Power circuits

6. a. Manual
   - b. Magnetic

7. a. Reversing
   - b. Reverse starter
   - c. Forward starter
   - d. Thermal overloads (heaters)
   - e. Starting
   - f. Line terminals L1, L2, L3
   - g. Auxiliary holding contacts
   - h. Housing for overload contacts
   - i. Reset button
   - j. Load terminals T1, T2, T3
   - k. Thermal overloads (heaters)
   - l. Coil terminals

8. a. Starting motors
   - b. Reversing motors
   - c. Braking motors to stop
   - d. Controlling speed of motors

ANSWERS TO TEST

9.

Parts	Contactors	Motor Starters
Holding contacts	Yes	Yes
Reset button	No	Yes
Coil	Yes	Yes
Overload contact	No	Yes
Thermal overloads (heaters)	No	Yes
Load terminals	Yes	Yes
Power contacts	Yes	Yes
Line terminals	Yes	Yes

10. a. Contactor does not provide running overload protection for motor
    b. Contactor is not designed for high inrush current for motor starting
    c. Contactor does not contain a set of overload contacts

11. a. Changes electrical signal to magnetic signal
    b. Activates mechanical portion of motor starter

12. a. Lamination
    b. Rivets
    c. Magnetic assembly
    d. Magnetic coil
    e. Armature
    f. Air gap
    g. Magnetic assembly
    h. Shading coil

13. Evaluated to the satisfaction of the instructor

14. Performance skills evaluated to the satisfaction of the instructor

AC MOTOR CONTROLS
UNIT VII

UNIT OBJECTIVE

After completing this unit, the student should be able to draw wiring control symbols and wiring diagrams, wire both a nonreversing and reversing starter, and determine the sequence of operation from a ladder diagram. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with alternating-current motor controls.
2. Match common wiring and control symbols to their correct names.
3. Describe types of controllers.
4. Name major headings for control circuits from *National Electrical Code.*
5. Match horsepower ratings to correct National Electrical Manufacturers Association (NEMA) industrial motor starters.
6. Match National Electrical Manufacturers Association (NEMA) motor-starter enclosures to their correct uses.
7. Complete wiring diagrams of alternating-current motor starters.
8. Use *National Electrical Code* to answer questions about motor control circuits.
9. Determine sequence of operations from ladder diagrams.
10. Use tables to select proper overload heater coils for different starters.
11. Demonstrate the ability to
    a. Change thermal overloads.
    b. Rewire a reversing starter.
    c. Diagram and wire a nonreversing motor starter with one start/stop station.

AC MOTOR CONTROLS
UNIT VII

SUGGESTED ACTIVITIES

I. Suggested activities

A. Make transparencies.

B. Provide students with objective sheet.

C. Discuss unit and specific objectives. State need for knowledge in each area.

D. Provide students with information, assignment, and job sheets.

E. Discuss information, assignment, and job sheets.

1. Discuss terms and definitions, using Information Sheet, Section I, and samples of actual control devices such as start buttons and limit switches.

2. Discuss symbols for control wiring, using Information Sheet, Section II, and Transparencies #1 through #6. Assignment Sheet #1 should be used to review this information. Show students many actual parts to assist them in grasping this new information.

3. Discuss types of controllers and their proper applications with reference to how *NEC* headings for control circuits affect the installation of the equipment material, using Information Sheet, Sections III and IV, and Assignment Sheet #2.

4. Discuss NEMA ratings and NEMA enclosure types, using Information Sheet, Sections V and VI, and Transparencies #7 and #8. Explain the need for NEMA standards and their relationship to the *NEC*.

5. Discuss wiring diagrams, using Information Sheet, Section VII. Use Transparency #9 to explain how ladder diagrams show control logic. Assignment Sheet #3 uses ladder diagrams to show sequence of control and to assist the student in understanding control logic. During the discussion, stress that students will find ladder diagrams more helpful than wiring diagrams in troubleshooting problems.

6. Explain how to size and change thermal-overload heaters, using Assignment Sheet #4 and Job Sheet #1.

7. Demonstrate the wiring of a reversing starter, using Job Sheet #2. Stress the safety factor of working with live voltages. Reference to Information Sheet, Section VII (B), may be helpful.

8. Demonstrate the wiring of a start/stop station, using Job Sheet #3. Reference to Information Sheet, Section VII (A), may be helpful.

SUGGESTED ACTIVITIES

F. Give test.

G. Reteach and retest if necessary.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Equipment and Representative Schematic Symbols
2. TM #2 — Equipment and Representative Schematic Symbols (Continued)
3. TM #3 — Equipment and Representative Schematic Symbols (Continued)
4. TM #4 — Schematic Symbols
5. TM #5 — Schematic Symbols (Continued)
6. TM #6 — Schematic Symbols (Continued)
7. TM #7 — NEMA Enclosures
8. TM #8 — NEMA Enclosures (Continued)
9. TM #9 — Ladder Diagram

E. Assignment sheets

1. Assignment Sheet #1 — Label Schematic Symbols
2. Assignment Sheet #2 — Use *National Electrical Code* to Answer Questions About Motor Control Circuits
3. Assignment Sheet #3 — Determine Sequence of Operations from Ladder Diagrams
4. Assignment Sheet #4 — Use Tables to Select Proper Overload Heater Coils for Different Starters

SUGGESTED ACTIVITIES

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Change Thermal Overloads
2. Job Sheet #2 — Rewire a Reversing Starter
3. Job Sheet #3 — Diagram and Wire a Nonreversing Motor Starter with One Start/Stop Station

H. Test

I. Answers to test

III. Unit reference — Rockis, Gary, and Glen Mazur. *Electrical Motor Controls.* Alsip, Illinois: American Technical Publishers, Inc., 1982.

AC MOTOR CONTROLS
UNIT VII

INFORMATION SHEET

I. Terms and definitions

A. Across-the-line — Method of motor starting that connects motor directly to supply line

(NOTE: Across-the-line is also called *full voltage*.)

B. Automatic starting — Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

C. Auxiliary contact — Contact provided in addition to the main circuit contacts but operated with the main contacts

D. Bimetal — Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

(NOTE: Bimetals are used in thermal-overload relays.)

E. Contactor — Device without overload protection; repeatedly establishes or interrupts an electric power circuit

F. Control circuit — Circuit that controls some function of a motor or device; carries performance signals

G. Control logic — Sequence of steps required to perform a specific function: signal, decision, actions

H. Jogging (inching) — Momentarily operating; moving a driven machine a small distance

I. Line diagram (ladder diagram) — Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

J. Low-voltage protection (LVP) — Function of magnetic control that releases contactor upon low voltage and requires manual restarting

K. Low-voltage release (LVR) — Function of magnetic control that releases contactor upon low voltage and automatically restarts when voltage is restored

L. Magnetic contactor — Contactor operated electromechanically

M. Multispeed starter — Starter designed to start a motor at a reduced speed and build to full speed in preset steps

INFORMATION SHEET

N. Overload relay — Device for protecting a motor from overload current or voltage

(NOTE: An overload relay does not necessarily protect against short circuit, but it does cause and maintain interruption from power supply until reset.)

O. Pilot light — Light used to indicate circuit status

P. Plugging — Braking by reverse line voltage or phase sequence of motor

(NOTE: Motor develops retarding force through plugging.)

Q. Push button — Switch, manually operable plunger, button, or actuating device

R. Reduced-voltage starter — Device that applies reduced voltage to motor during starting

(NOTE: Reduced-voltage starters are also called *reduced-inrush starters*.)

S. Relay — Electromechanical device operated by a coil; uses contacts to make or break control circuits

T. Remote control — Device that controls electrical apparatus from some distance

U. Selector switch — Manually operated multiposition switch

(NOTE: The selector switch is also called a *multiple-contact switch*.)

V. Solenoid — Magnetic coil used to operate a relay, contactor, or starter

W. Starter — Control device with electric contactor with overload protection; designed to protect motor from a voltage inrush during starting

X. Timer — Pilot device that delays closing or opening of a circuit for a specific time; may be motor-driven, solenoid-actuated, or electronic

Y. Wiring diagram — Schematic consisting of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power-circuit wiring

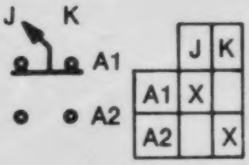
INFORMATION SHEET

II. Common wiring and control symbols (Figures 1-10; Transparencies #1-#6; Assignment Sheet #1)

(NOTE: The NEMA standard symbols include many symbols seldom used by engineers and technicians. Those presented here, are the ones most often used.)

A. Two-position selector (X-contacts closed)

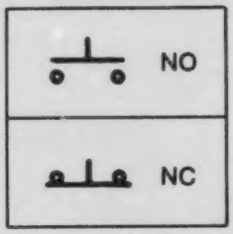
FIGURE 1



	J	K
A1	X	
A2		X

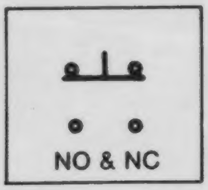
B. Single-circuit momentary-contact push button

FIGURE 2



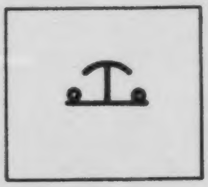
C. Double-circuit momentary-contact push button

FIGURE 3



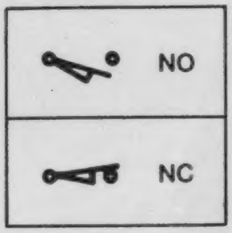
D. Mushroom-head momentary-contact push button

FIGURE 4



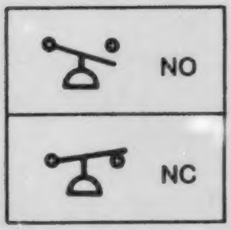
E. Limit switch

FIGURE 5



F. Pressure and vacuum switch

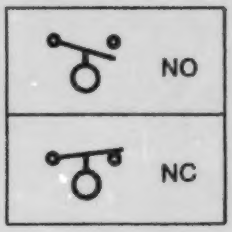
FIGURE 6



INFORMATION SHEET

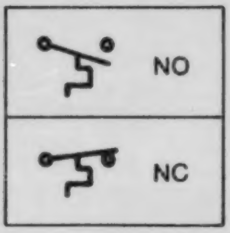
G. Liquid-level switch

FIGURE 7



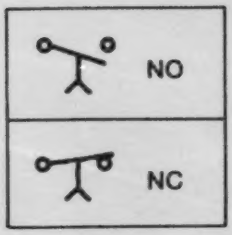
H. Temperature-actuated switch

FIGURE 8



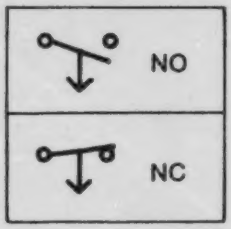
I. Energized timed contact

FIGURE 9



J. Deenergized timed contact

FIGURE 10



III. Types of controllers

A. Manual — Starters operated by hand

B. Semiautomatic — Starters controlled by manual pilot switches, push-button switches, drum switches, or similar equipment

C. Automatic — Starters activated by sensing devices, float switches, limit switches, temperature-controlled contacts, or similar devices

IV. Major headings for control circuits from the *National Electrical Code* (Assignment Sheet #2)

(NOTE: Full text may be found in Articles 430-72, 430-73, and 430-74 of the *National Electrical Code*.)

A. Definition of motor control circuit

B. Overcurrent protection

INFORMATION SHEET

C. Conductor protection

D. Control circuit transformer

E. Mechanical protection of conductor

F. Disconnection of control circuit

G. Control transformer in controller

V. Horsepower ratings of NEMA industrial motor starters (Table 1)

(NOTE: Those motor starters listed below are the sizes most commonly used in industry. Table 1 charts the standard NEMA ratings of AC contactors [60 Hz] for all motor starters.)

A. Size 00 — 2 horsepower at 460 volts

B. Size 0 — 5 horsepower at 460 volts

C. Size 1 — 10 horsepower at 460 volts

D. Size 2 — 25 horsepower at 460 volts

E. Size 3 — 50 horsepower at 460 volts

F. Size 4 — 100 horsepower at 460 volts

EXAMPLE:

TABLE 1

Size	Eight-Hour Open Rating (A)	Power (hp)				
		Three Phase			Single Phase	
		200 V	230 V	460 V	115 V	230 V
00	9	1 1/2	1 1/2	2	1/3	1
0	18	3	3	5	1	2
1	27	7 1/2	7 1/2	10	2	3
2	45	10	15	25	3	7 1/2
3	90	25	30	50	—	—
4	135	40	50	100	—	—
5	270	75	100	200	—	—
6	540	150	200	400	—	—
7	810	—	300	600	—	—
8	1,215	—	450	900	—	—
9	2,250	—	800	1,600	—	—

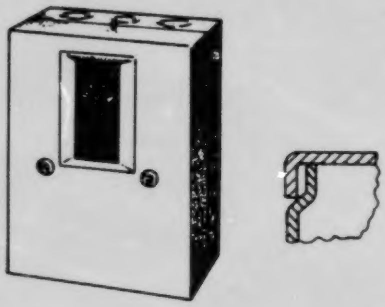
INFORMATION SHEET

VI. Uses for types of NEMA motor-starter enclosures (Figures 11-16; Transparencies #7 and #8)

A. NEMA Type 1 — Intended for indoor use

EXAMPLE: Surface-mounted air compressor in a service station

FIGURE 11

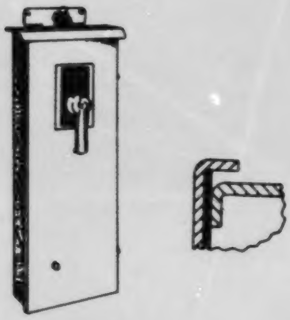


Used with permission of the Allen-Bradley Company, Milwaukee, Wisconsin.

B. NEMA Type 3R — Intended for use outdoors where rain and sleet are present

EXAMPLE: Roof-mounted air-conditioning unit

FIGURE 12



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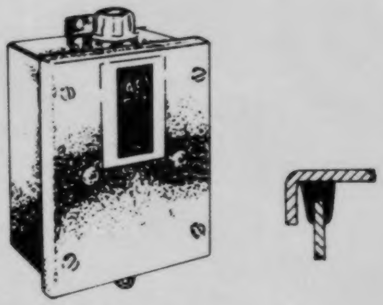
INFORMATION SHEET

C. NEMA Type 4 — Intended for use indoors or outdoors where windblown dust, rain, or hose-directed water is present

EXAMPLE: Inside a car-wash bay

FIGURE 13



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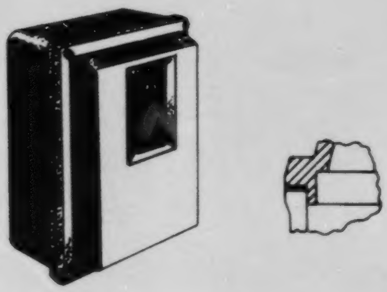
D. NEMA Type 4X — Intended for use in corrosive or chemical atmospheres

EXAMPLE: Fertilizer plants

FIGURE 14



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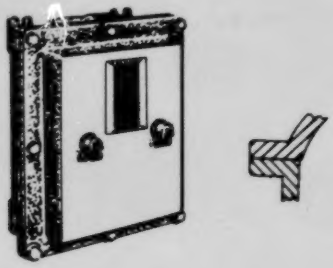
INFORMATION SHEET

E. NEMA Type 7 — Intended for use indoors in hazardous locations where Class I, Group C or D conditions exist

EXAMPLE: Oil-refinery installations

FIGURE 15



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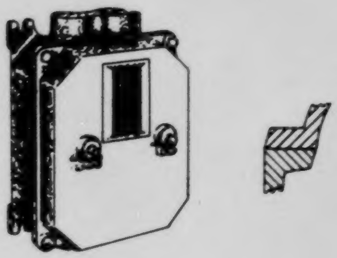
F. NEMA Type 9 — Intended for use indoors in hazardous locations where Class II, Groups E, F, and G conditions exist

EXAMPLE: Grain elevators

FIGURE 16



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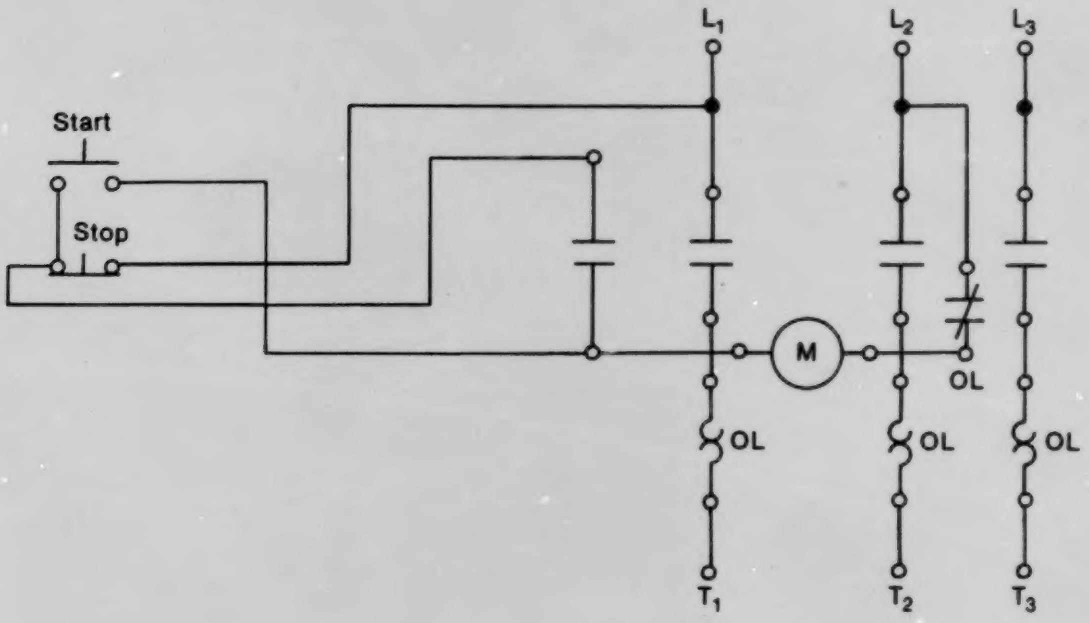
INFORMATION SHEET

VII. Wiring diagrams of alternating-current motor starters (Transparency #9; Assignment Sheet #3)

(NOTE: The service technician will find ladder diagrams more helpful than wiring diagrams when troubleshooting problems. Both types of diagrams are presented here so that comparisons can be made.)

A. Three-phase nonreversing with remote start/stop station (Figure 17)

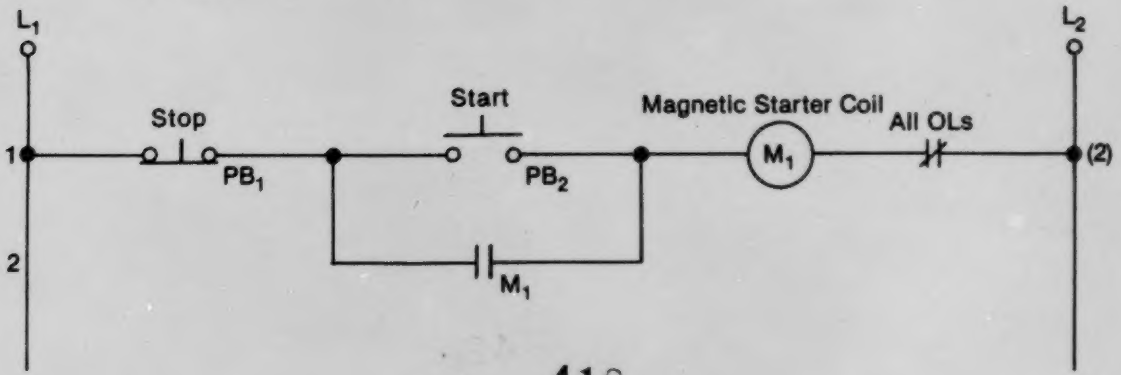
FIGURE 17



L_1
L_2
L_3
Start
Stop
M
OL
OL
OL
OL
T_1
T_2
T_3

EXAMPLE: Ladder diagram (Figure 18)

FIGURE 18

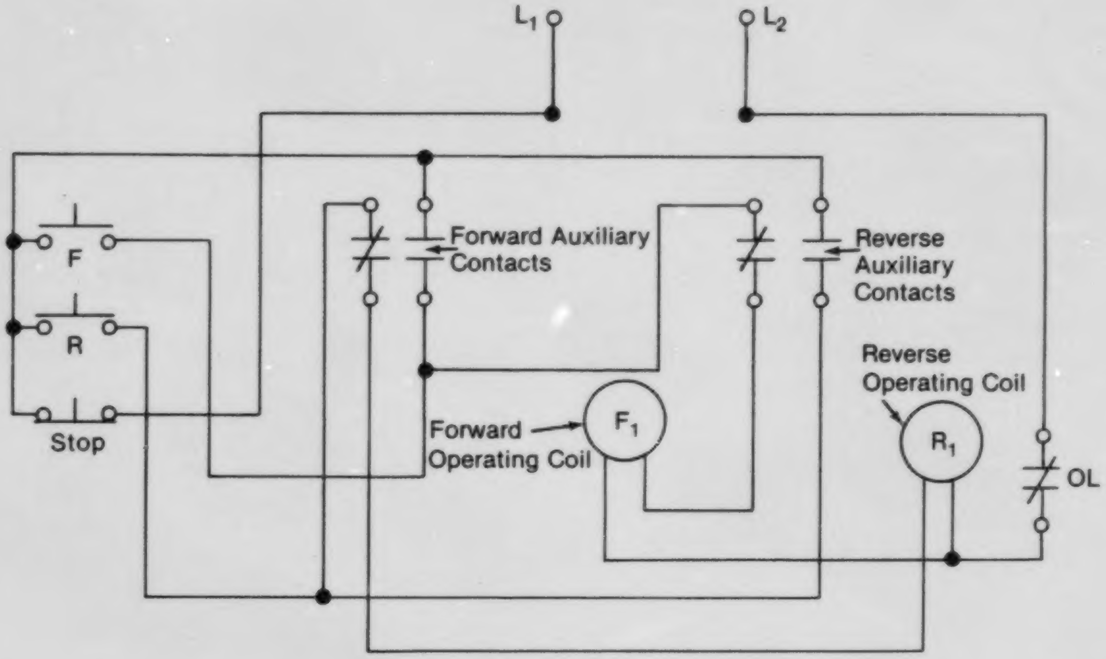


L_1
L_2
Stop
Start
Magnetic Starter Coil
All OLs
1
(2)
PB_1
PB_2
M_1
M_1
2

INFORMATION SHEET

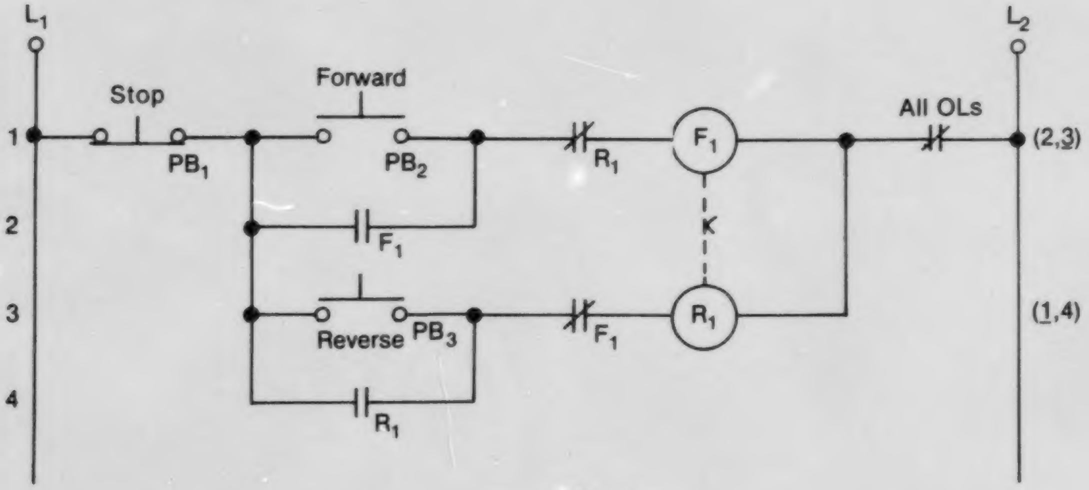
B. Reversing starter with remote forward/reverse stop station (Figure 19)

FIGURE 19


L_1
L_2
F
R
Stop
Forward Auxiliary Contacts
Reverse Auxiliary Contacts
Reverse Operating Coil
Forward Operating Coil
F_1
R_1
OL

EXAMPLE: Ladder diagram (Figure 20)

FIGURE 20

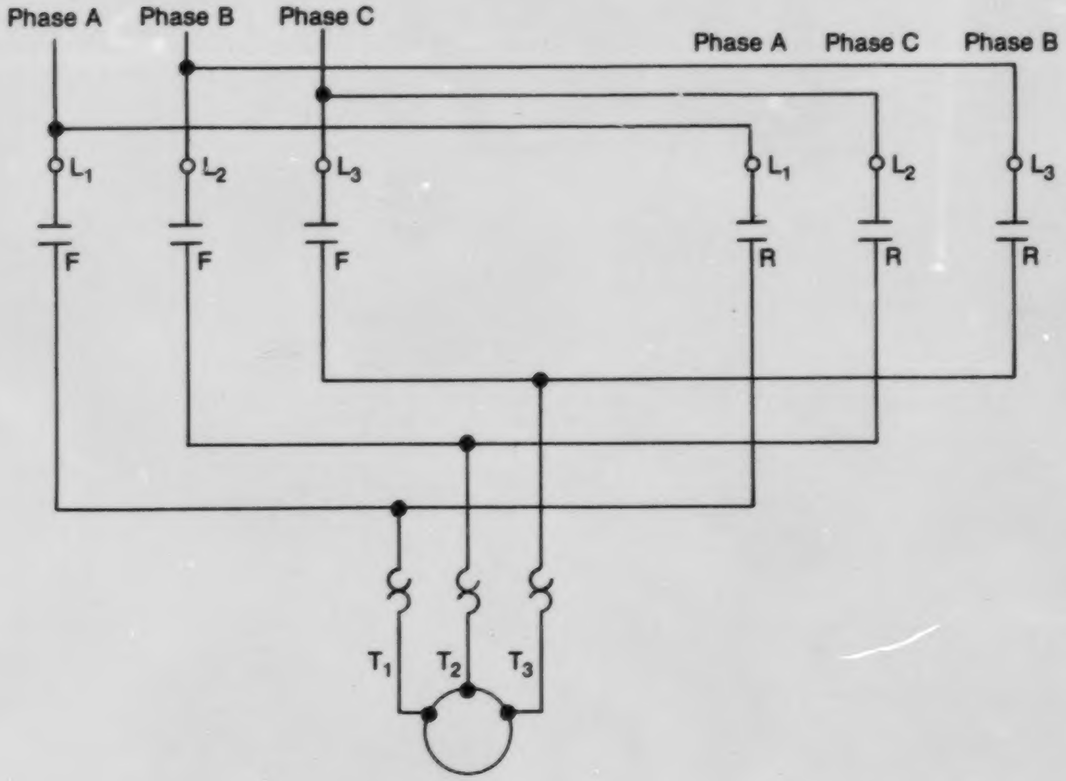

L_1
L_2
1
2
3
4
Stop
PB_1
Forward
PB_2
R_1
F_1
All OLs
(2,3)
F_1
K
Reverse
PB_3
F_1
R_1
(1,4)
R_1

INFORMATION SHEET

(NOTE: The reversing of the motor is actually accomplished by reversing any two line inputs. See the power diagram for the three-phase reversing starter in Figure 21.)

EXAMPLE: Power diagram (Figure 21)

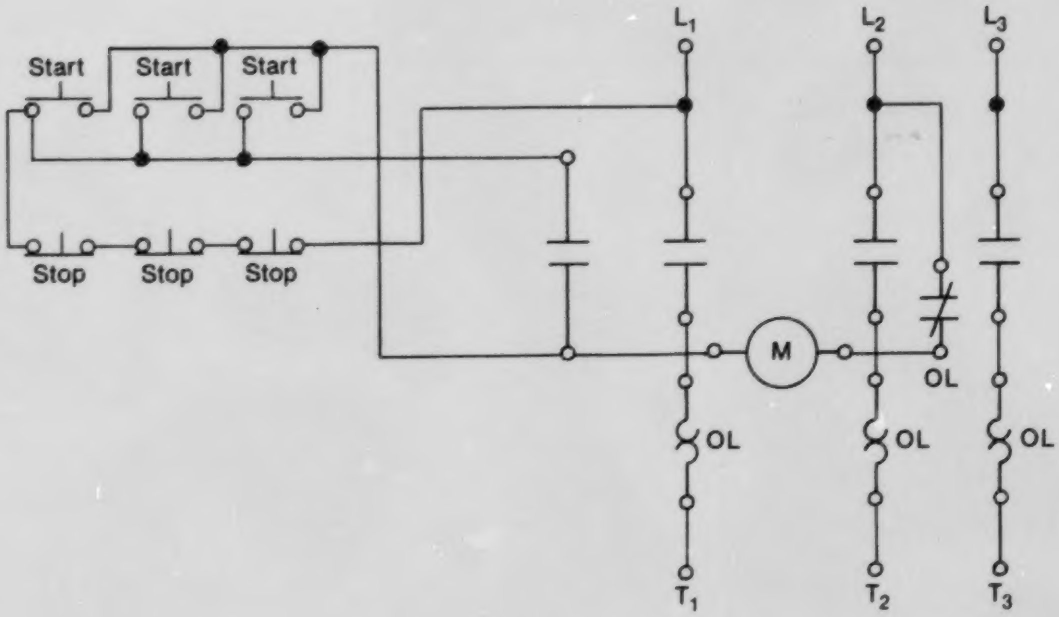
FIGURE 21


Phase A
Phase B
Phase C
Phase A
Phase C
Phase B
L_1
L_2
L_3
F
F
F
L_1
L_2
L_3
R
R
R
T_1
T_2
T_3

INFORMATION SHEET

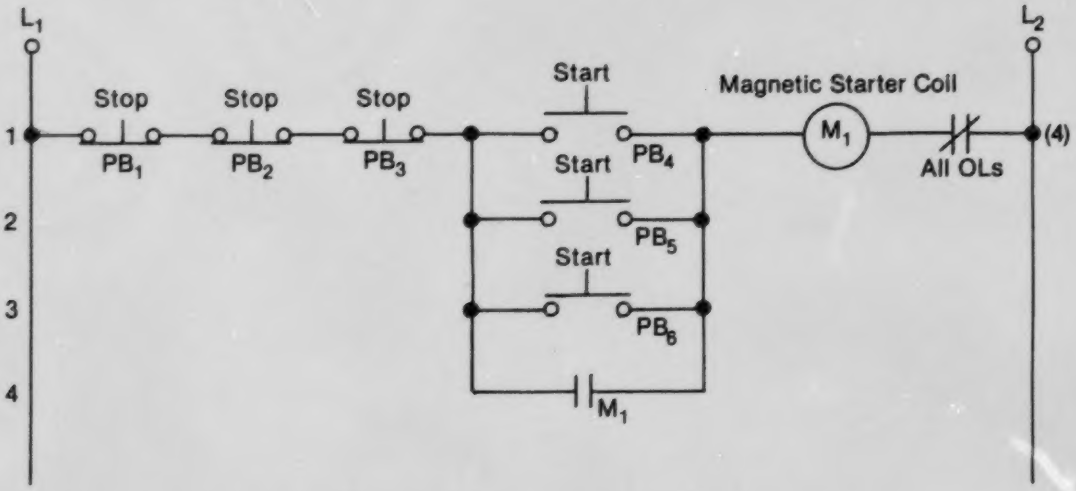
C. Multiple remote start/stop stations (Figure 22)

FIGURE 22


Start
Start
Start
Stop
Stop
Stop
L_1
L_2
L_3
M
OL
OL
OL
OL
T_1
T_2
T_3

EXAMPLE: Ladder diagram (Figure 23)

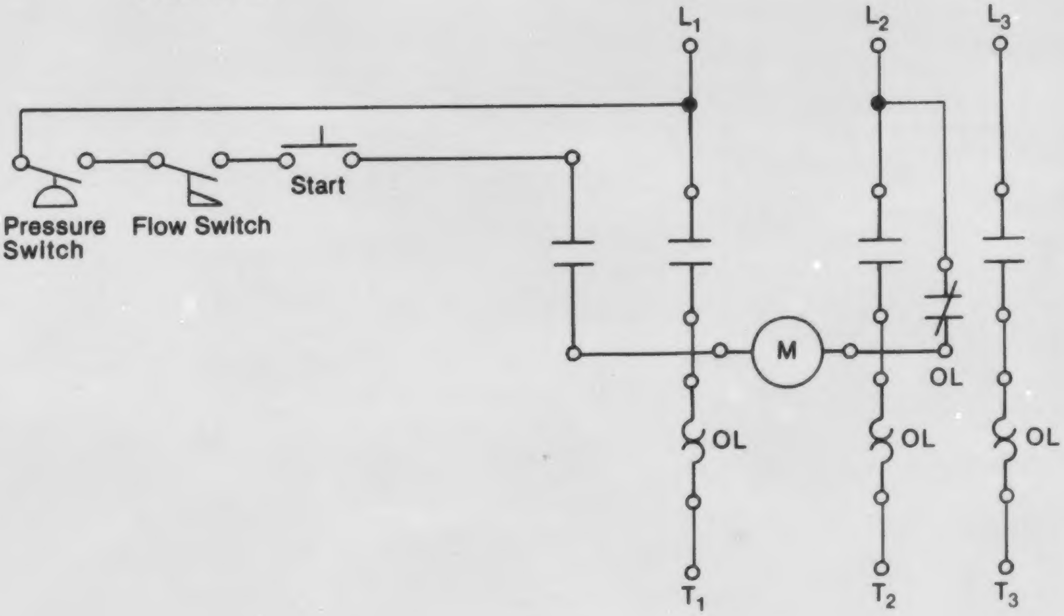
FIGURE 23


L_1
L_2
1
2
3
4
Stop
Stop
Stop
PB_1
PB_2
PB_3
Start
Start
Start
PB_4
PB_5
PB_6
M_1
Magnetic Starter Coil
M_1
All OLs
(4)

INFORMATION SHEET

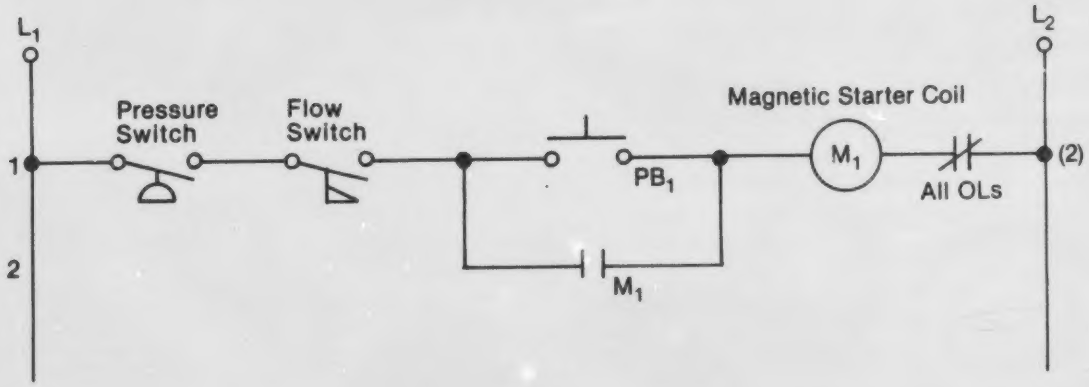
D. Pump circuit with pressure and flow switches acting as stop switches (Figure 24)

FIGURE 24


L1
L2
L3
Pressure Switch
Flow Switch
Start
M
OL
OL
OL
OL
T1
T2
T3

EXAMPLE: Ladder diagram (Figure 25)

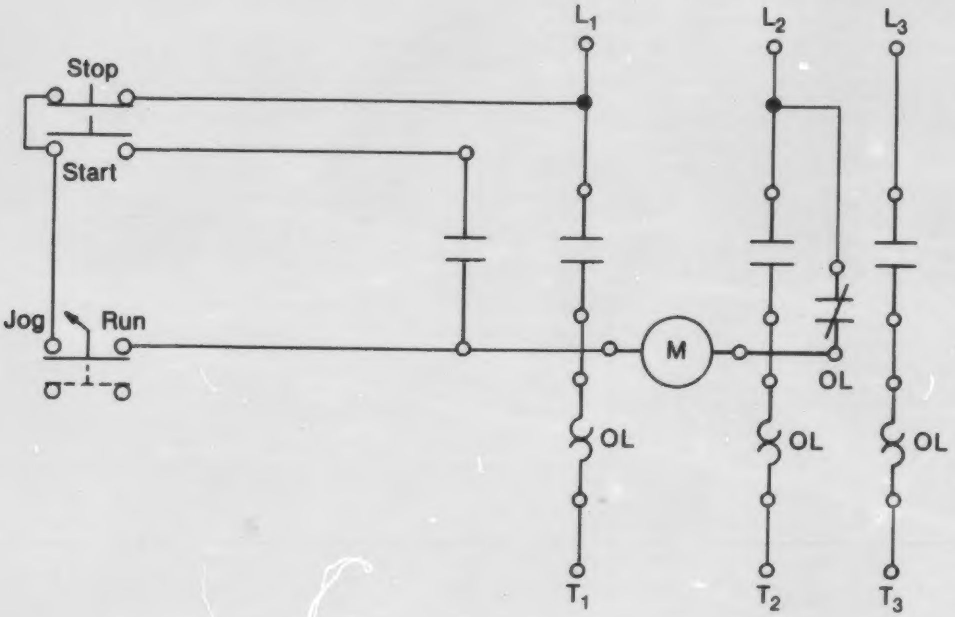
FIGURE 25


L1
L2
1
2
Pressure Switch
Flow Switch
PB1
Magnetic Starter Coil
M1
All OLs
(2)
M1

INFORMATION SHEET

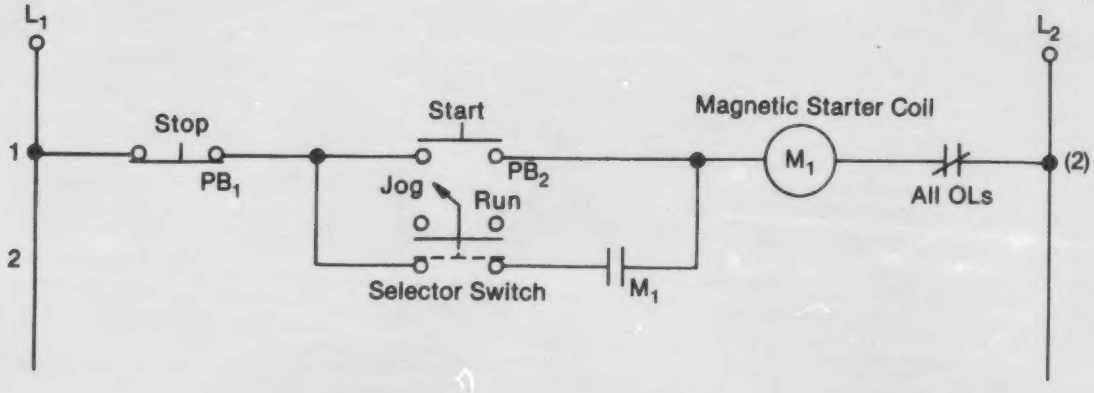
E. Start/stop circuit with selector switch for jogging motor (Figure 26)

FIGURE 26


L_1
L_2
L_3
Stop
Start
Jog
Run
M
OL
OL
OL
OL
T_1
T_2
T_3

EXAMPLE: Ladder diagram (Figure 27)

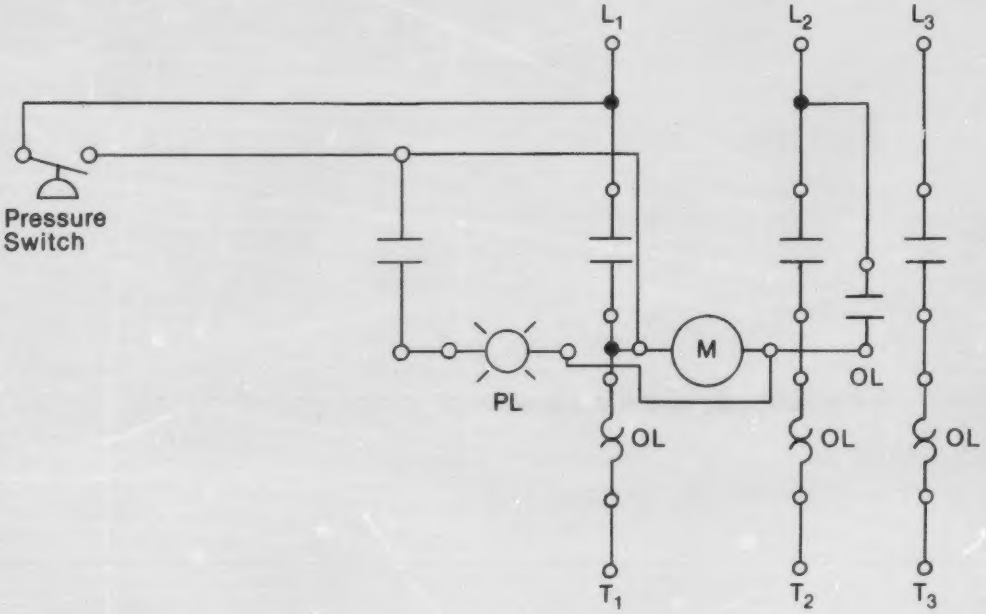
FIGURE 27


L_1
L_2
1
2
Stop
PB_1
Start
PB_2
Jog
Run
Selector Switch
M_1
Magnetic Starter Coil
M_1
All OLs
(2)

INFORMATION SHEET

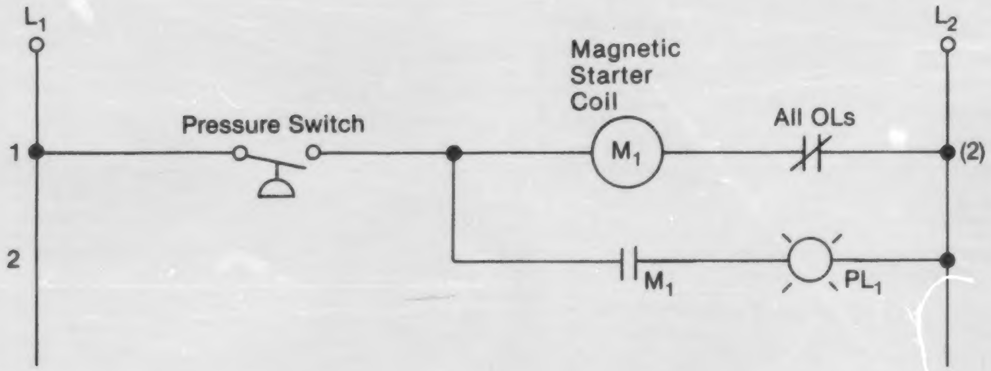
F. Typical control circuit for an air compressor with pilot light (Figure 28)

FIGURE 28


L1
L2
L3
Pressure Switch
M
PL
OL
OL
OL
OL
T1
T2
T3

EXAMPLE: Ladder diagram (Figure 29)

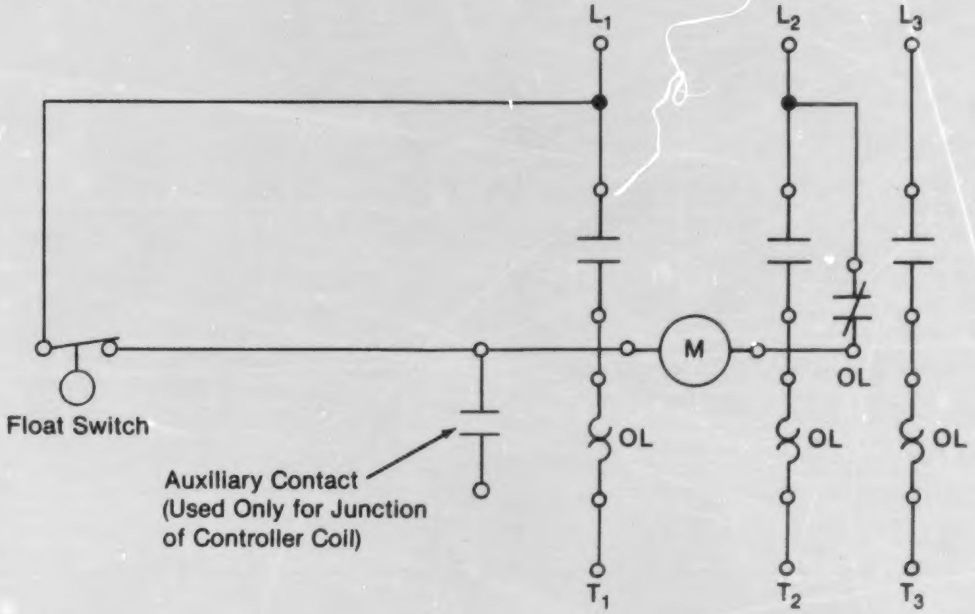
FIGURE 29


L1
L2
1
2
Pressure Switch
Magnetic Starter Coil
M1
All OLs
(2)
M1
PL1

INFORMATION SHEET

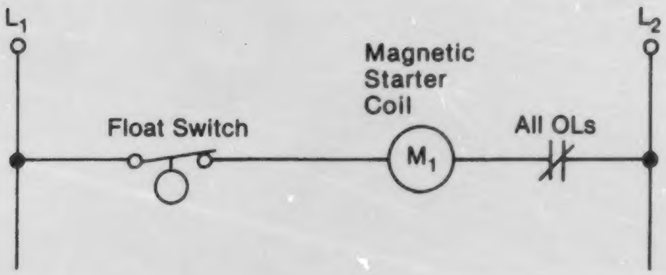
G. Motor starter with float switch as start/stop; no holding contacts (Figure 30)

FIGURE 30

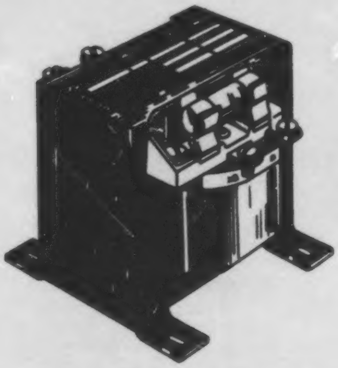

L1
L2
L3
M
OL
OL
OL
OL
Float Switch
Auxiliary Contact
(Used Only for Junction
of Controller Coil)
T1
T2
T3

EXAMPLE: Ladder diagram (Figure 31)

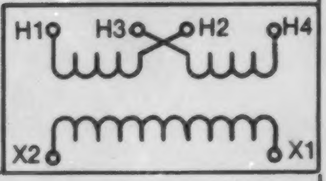
FIGURE 31

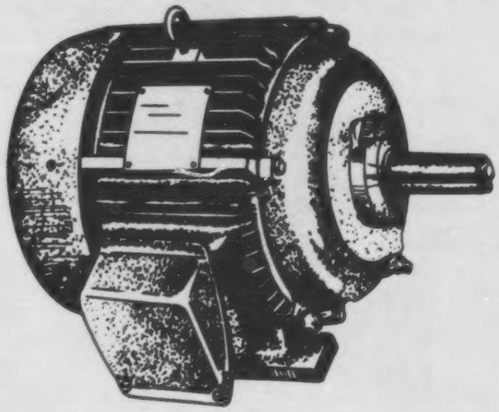

L1
L2
Magnetic
Starter
Coil
Float Switch
M1
All OLs

Equipment and Representative Schematic Symbols

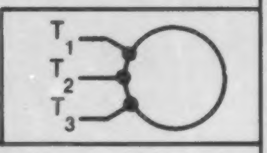


Control Transformer

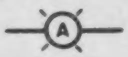
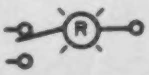


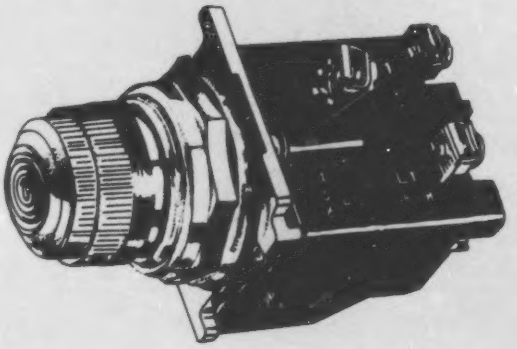


Three-Phase Motor



Pilot Lights

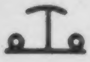
Indicate Color by Letter	
Non-Push-to-Test	Push-to-Test
	



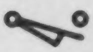
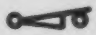
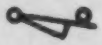
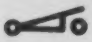
Used with permission of the Allen-Bradley Company and Eaton Corp., Cutler-Hammer Products, Milwaukee, Wisconsin, and Westinghouse Electric Corporation, Buffalo, New York.

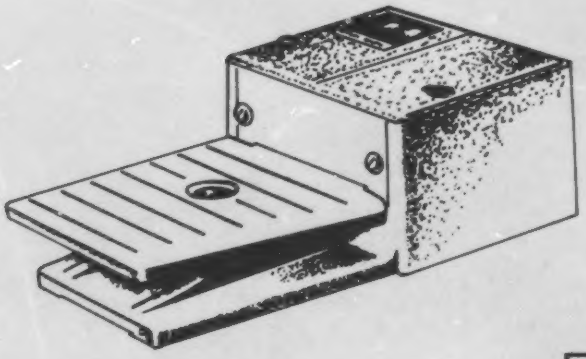
Equipment and Representative Schematic Symbols

(Continued)

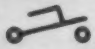
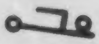
Push Button, Mushroom Head	
	

Limit Switches

Normally Open	Normally Closed	Held Closed	Held Open
			



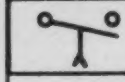
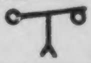
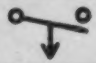
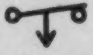
Foot Switches

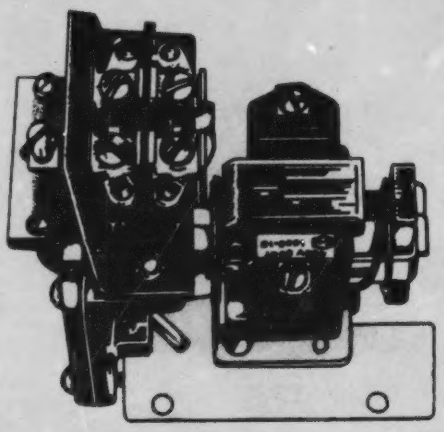
Normally Open	Normally Closed
	

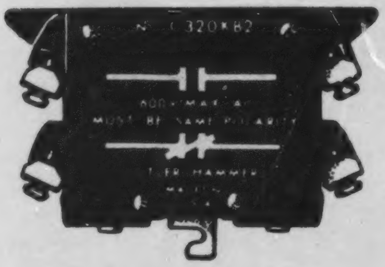
Used with permission of the Allen-Bradley Company and Eaton Corp., Cutler-Hammer Products, Milwaukee, Wisconsin. Source for limit switch: Westinghouse Electric Corporation, Buffalo, New York.

Equipment and Representative Schematic Symbols
(Continued)

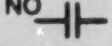
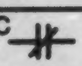
Pneumatic Timer

Timed Contacts — Contact Action Retarded After Coil Is:			
Energized		Deenergized	
NOTC	NCTC	NOTC	NCTC
			

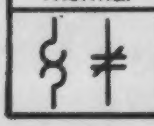
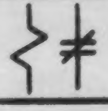


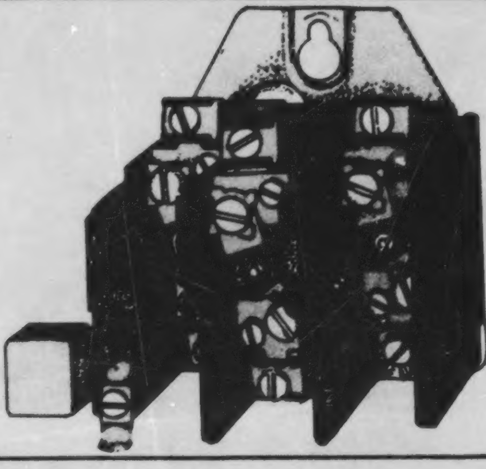


Auxiliary Contacts

NO 	NC 

Overload Relays

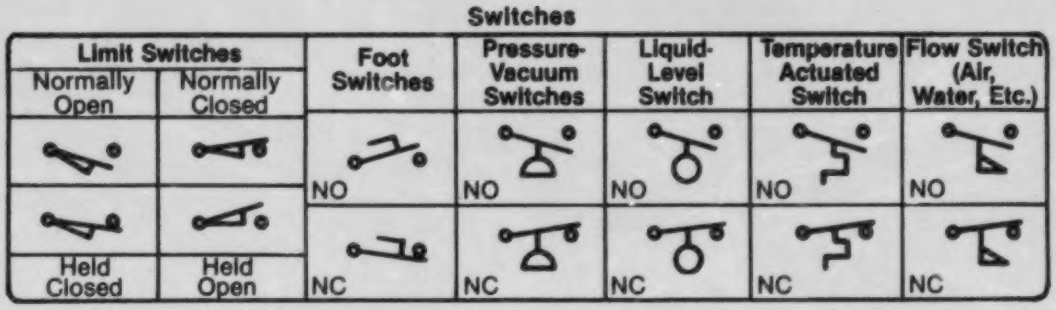
Thermal	Magnetic
	

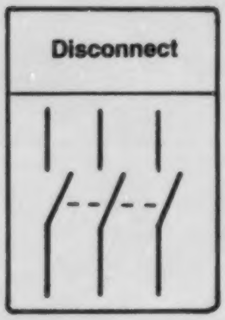


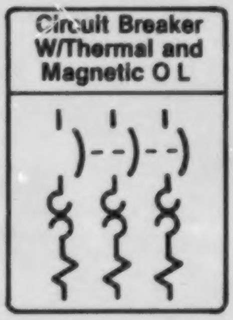
Used with permission of Eaton Corp., Cutler-Hammer Products, Milwaukee, Wisconsin.

Schematic Symbols

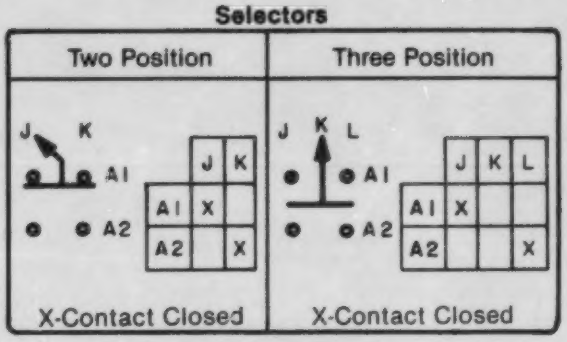
Switches


Limit Switches
Normally Open
Normally Closed
Held Closed
Held Open
Foot Switches
NO
NC
Pressure-Vacuum Switches
NO
NC
Liquid-Level Switch
NO
NC
Temperature Actuated Switch
NO
NC
Flow Switch (Air, Water, Etc.)
NO
NC

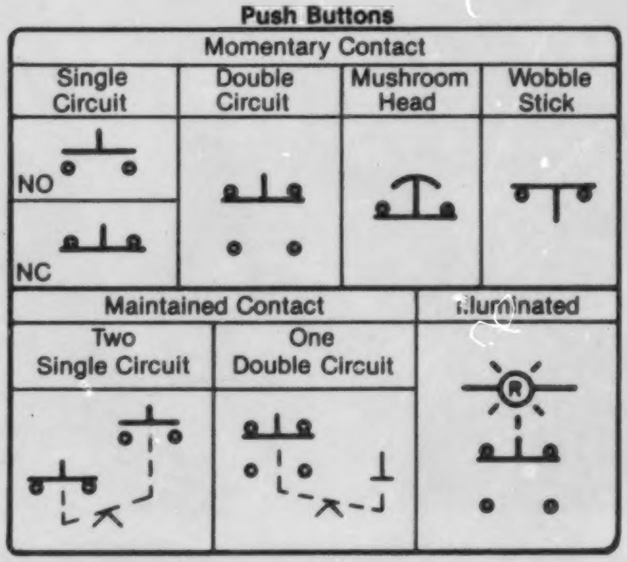

Disconnect


Circuit Breaker W/Thermal and Magnetic O L

Selectors


Two Position
J
K
A1
A2
J
K
A1
X
A2
X
X-Contact Closed
Three Position
J
K
L
A1
A2
J
K
L
A1
X
A2
X
X-Contact Closed

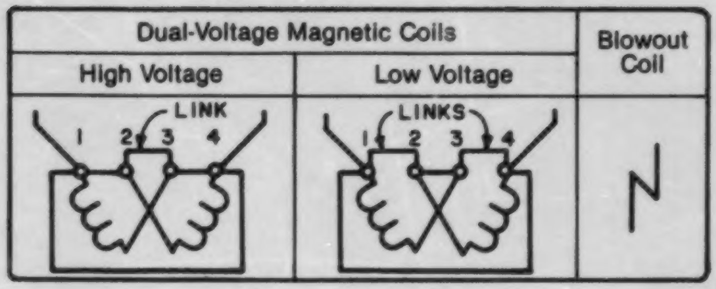
Push Buttons


Momentary Contact
Single Circuit
NO
NC
Double Circuit
Mushroom Head
Wobble Stick
Maintained Contact
Two Single Circuit
One Double Circuit
Illuminated
R

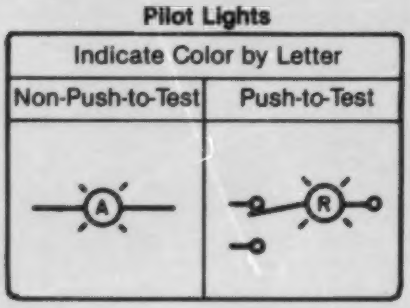
Source: *Electrical Motor Controls* by Gary Rockis and Glen Mazur, 1982, American Technical Publishers, Inc.

Schematic Symbols
(Continued)

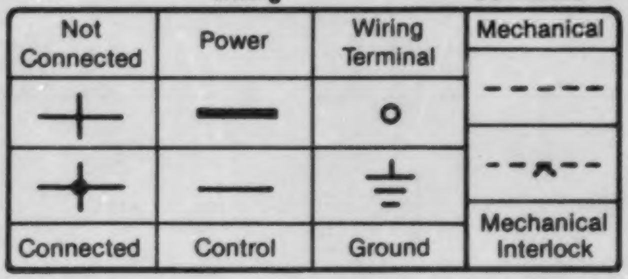
Coils


Dual-Voltage Magnetic Coils
High Voltage
LINK
1
2
3
4
Low Voltage
LINKS
1
2
3
4
Blowout Coil

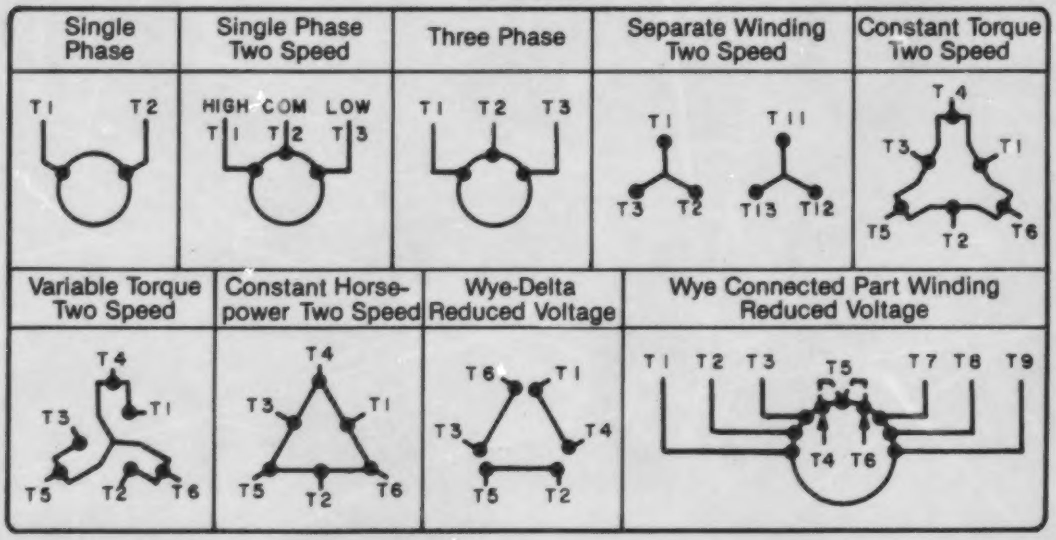
Pilot Lights


Indicate Color by Letter
Non-Push-to-Test
A
Push-to-Test
R

Wiring **Connections**


Not Connected
Connected
Power
Control
Wiring Terminal
Ground
Mechanical
Mechanical Interlock

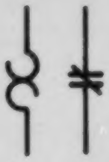
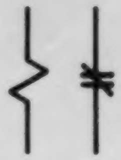
AC Motors


Single Phase
T1
T2
Single Phase Two Speed
HIGH
COM
LOW
T1
T2
T3
Three Phase
T1
T2
T3
Separate Winding Two Speed
T1
T3
T2
T11
T13
T12
Constant Torque Two Speed
T4
T3
T1
T5
T2
T6
Variable Torque Two Speed
T4
T3
T1
T5
T2
T6
Constant Horsepower Two Speed
T4
T3
T1
T5
T2
T6
Wye-Delta Reduced Voltage
T6
T1
T3
T4
T5
T2
Wye Connected Part Winding Reduced Voltage
T1
T2
T3
T5
T7
T8
T9
T4
T6

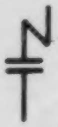
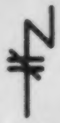
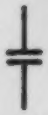
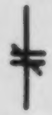
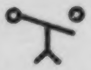
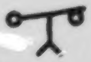
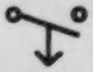
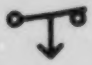
Source: *Electrical Motor Controls* by Gary Rockis and Glen Mazur, 1982, American Technical Publishers, Inc.

Schematic Symbols
(Continued)

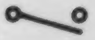
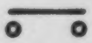
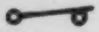
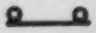
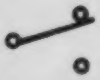
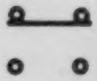
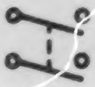
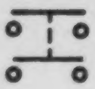
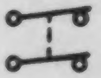
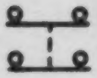
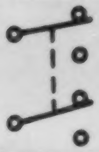
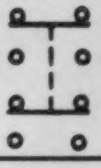
Overload Relays

Thermal	Magnetic
	

Contacts

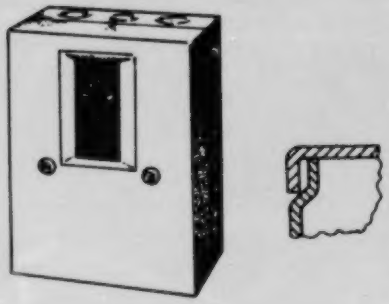
Instant Operating				Timed Contacts — Contact Action Retarded After Coil Is:			
With Blowout		Without Blowout		Energized		Deenergized	
NO	NC	NO	NC	NOTC	NCTO	NOTO	NCTC
							

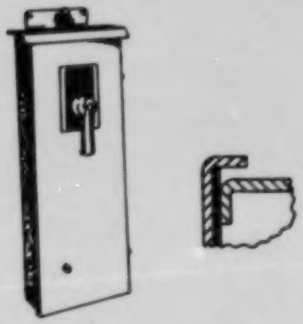
Supplementary Contact Symbols

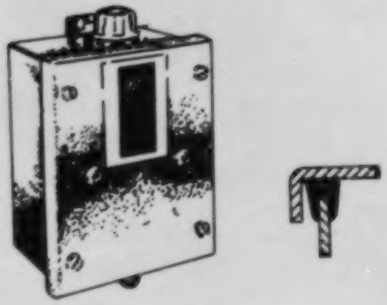
SPST NO		SPST NC		SPDT		Terms
Single Break	Double Break	Single Break	Double Break	Single Break	Double Break	
						SPST — Single Pole Single Throw SPDT — Single Pole Double Throw DPST — Double Pole Single Throw DPDT — Double Pole Double Throw NO — Normally Open NC — Normally Closed
DPST, 2 NO		DPST, 2 NC		DPDT		
Single Break	Double Break	Single Break	Double Break	Single Break	Double Break	
						

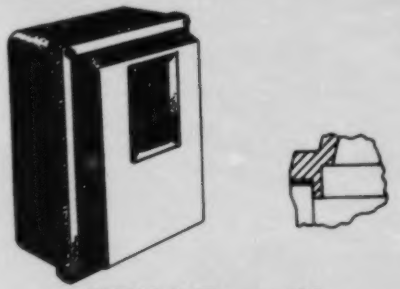
Source: *Electrical Motor Controls* by Gary Rockis and Glen Mazur, 1982, American Technical Publishers, Inc.

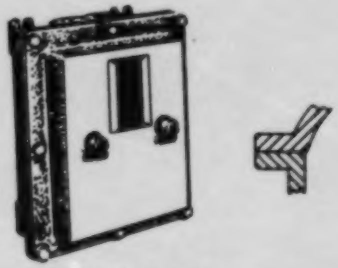
NEMA Enclosures

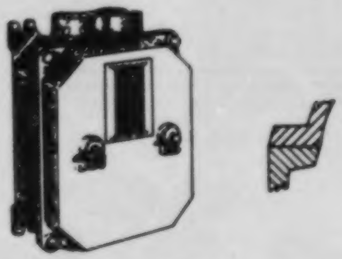

NEMA Type 1
Surface Mounting


NEMA Type 3R


NEMA Type 4


NEMA Type 4X
Nonmetallic,
Corrosion-Resistant
Glass Polyester


NEMA Type 7
For Hazardous
Gas Locations
Bolted Enclosure


NEMA Type 9
For Hazardous
Dust Locations

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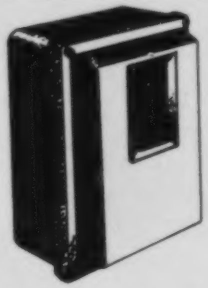
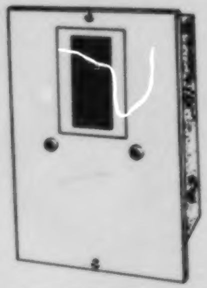
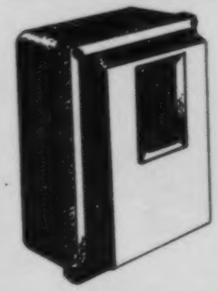
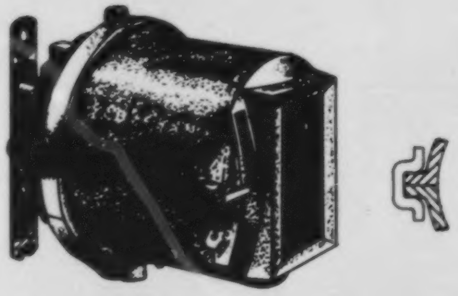
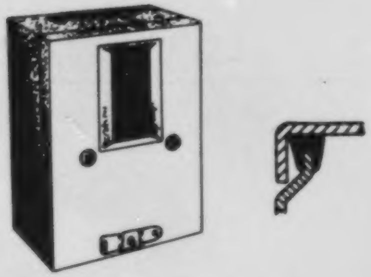
NEMA Enclosures
(Continued)


NEMA Type 13


NEMA Type 1
Flush Mounting

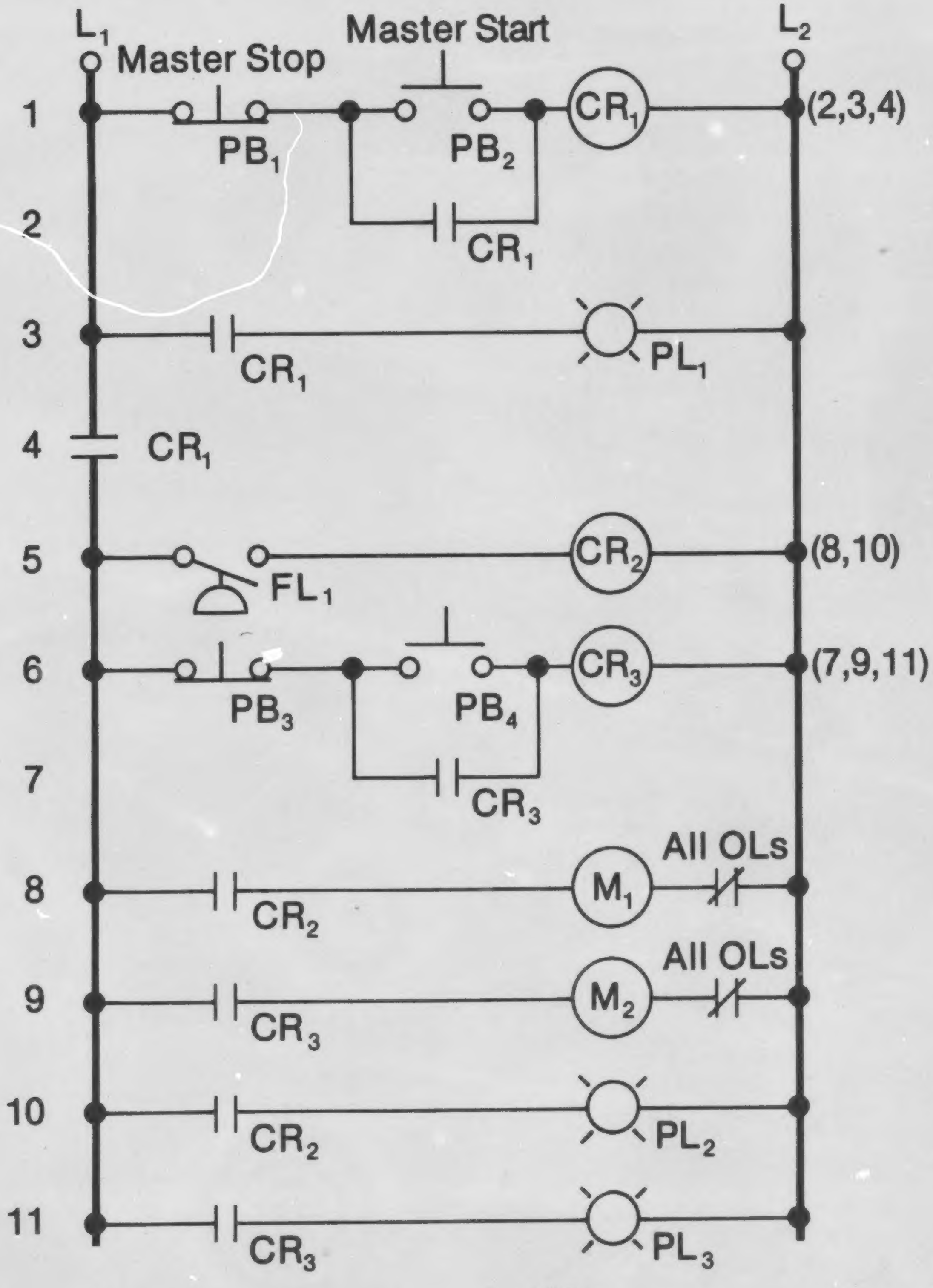

NEMA Type 6P


NEMA Type 3R, 7, and 9
Unilock Enclosure
For Hazardous
Locations


NEMA Type 12

Used with permission of the Allen-Bradley Company, Milwaukee, Wisconsin.

Ladder Diagram


L1
L2
Master Stop
Master Start
1
2
3
4
5
6
7
8
9
10
11
PB1
PB2
CR1
(2,3,4)
CR1
CR1
PL1
CR1
FL1
CR2
(8,10)
PB3
PB4
CR3
(7,9,11)
CR3
CR2
M1
All OLs
CR3
M2
All OLs
CR2
PL2
CR3
PL3

AC MOTOR CONTROLS
UNIT VII

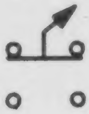
ASSIGNMENT SHEET #1 — LABEL SCHEMATIC SYMBOLS

NAME ______________________________ SCORE ______________

The industrial electrician must be able to identify schematic symbols engineers use on diagrams.

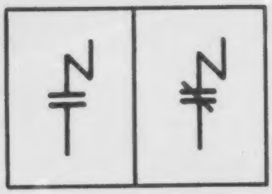
Label the following symbols, using standard industry terms. You may refer to Transparencies #1 through #6 if necessary, but first see how many you can label without help.

EXAMPLE:



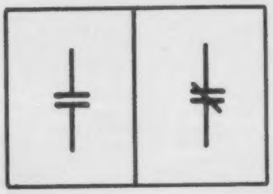
Two-position selector

A. Contacts



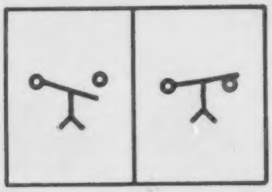
1. ______________________________

____



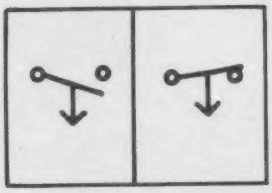
2. ______________________________

____



3. ______________________________

____

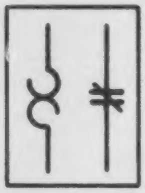


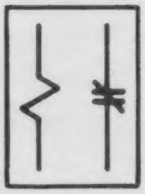
4. ______________________________

____

ASSIGNMENT SHEET #1

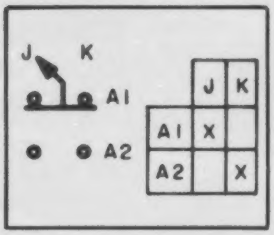
B. Overload relays

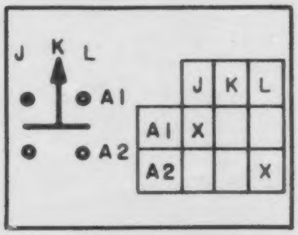




1. ______________________ 2. ______________________

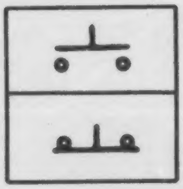
C. Selectors (X-contacts closed)

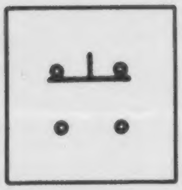

J
K
A1
A2
J
K
A1
X
A2
X

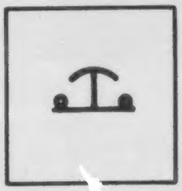

J
K
L
A1
A2
J
K
L
A1
X
A2
X

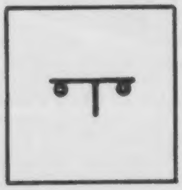
1. ______________________ 2. ______________________

D. Push buttons



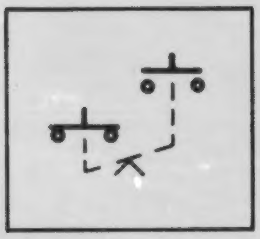




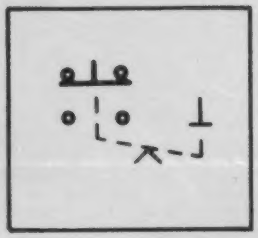


1. __________ 2. __________ 3. __________ 4. __________

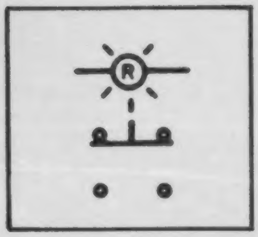
ASSIGNMENT SHEET #1



5. ________________________
____

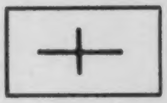


6. ________________________
____

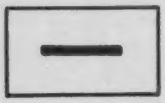


7. ________________________
____

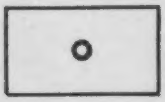
E. Wiring and connections



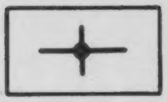
1. ________________________



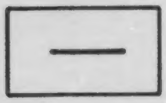
2. ________________________



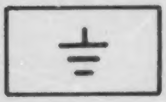
3. ________________________



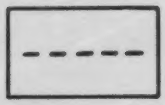
4. ________________________



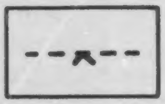
5. ________________________



6. ________________________

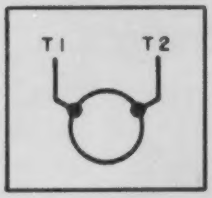


7. ____

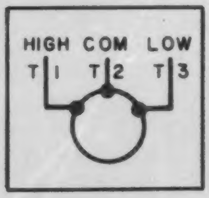


8. ____

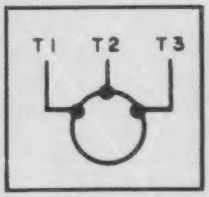
F. AC motors



1. ________________________


HIGH
COM
LOW
T1
T2
T3

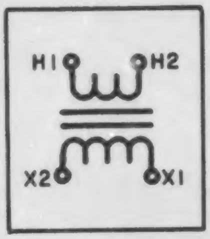
2. ________________________



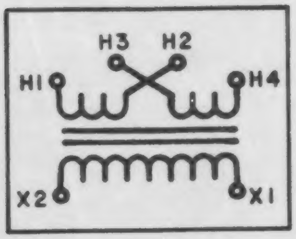
3. ________________________

ASSIGNMENT SHEET #1

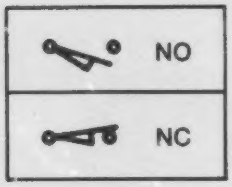
G. Control transformers



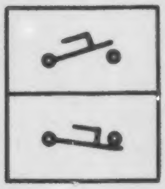
1. ______________________________


H3
H2
H1
H4
X2
X1

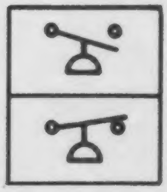
2. ______________________________



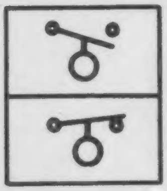
H. ______________________________



I. ______________________________

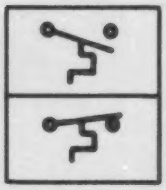


J. ______________________________

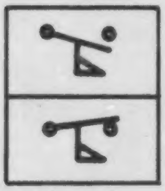


K. ______________________________

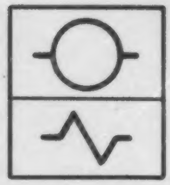
ASSIGNMENT SHEET #1



L. ______________________



M. ______________________



N. ______________________

AC MOTOR CONTROLS
UNIT VII

ASSIGNMENT SHEET #2 — USE *NATIONAL ELECTRICAL CODE* TO ANSWER QUESTIONS ABOUT MOTOR CONTROL CIRCUITS

NAME ______________________________ SCORE ______________

The industrial electrician must be able to interpret and apply the *National Electrical Code* by properly wiring all motor control circuits according to information found in Article 430.

Use the *National Electrical Code* to answer the following questions.

A. State the section of the *National Electrical Code* that deals with overcurrent protection.

____

B. List two exceptions for conductor protection in motor control circuits.

1. ____

2. ____

C. Is a transformer used to step down voltage for motor control circuits exempt from Article 430? Write an "X" in the appropriate blank.

Yes _____ No _____

D. Describe the *National Electrical Code* requirements for protecting control conductors.

____

E. State time when motor control circuits must be disconnected.

____

F. Define a motor control circuit.

____

____

G. State procedures for protecting conductors in control circuits.

____

AC MOTOR CONTROLS
UNIT VII

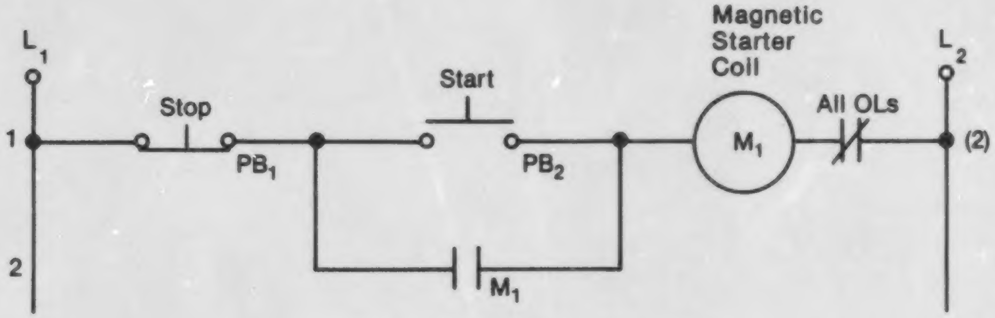
ASSIGNMENT SHEET #3 — DETERMINE SEQUENCE OF OPERATIONS FROM LADDER DIAGRAMS

NAME ______________________________ SCORE ______________

Being able to look at a schematic diagram and determine the sequence of operations is one of the skills essential for efficient troubleshooting. Such interpretation is a vital part of maintenance work.

After reviewing the example below and related material in Section VII of the Information Sheet, analyze each of the following ladder diagrams for their sequence of operation. Write the steps for each operation in sequence as shown in the example.

EXAMPLE:



A. Start

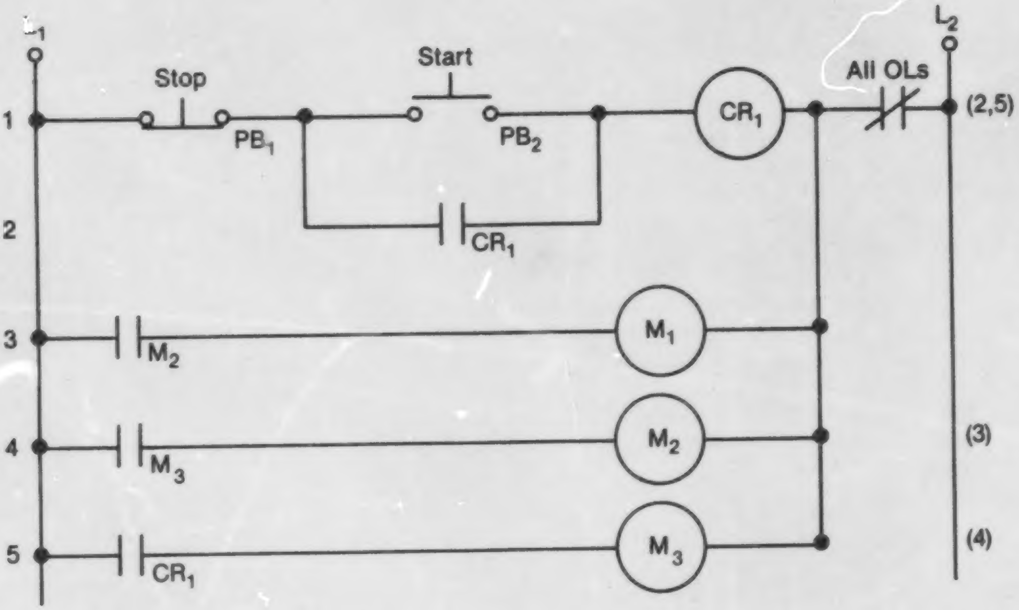
1. Start button depressed
2. Energizes coil M1
3. Closes contact M1
4. Permits release of start button as contact M1 keeps coil M1 energized

B. Stop

1. Stop button depressed
2. Deenergizes coil M1
3. Opens contact M1
4. Leaves coil M1 deenergized because start button is normally open

ASSIGNMENT SHEET #3

A.

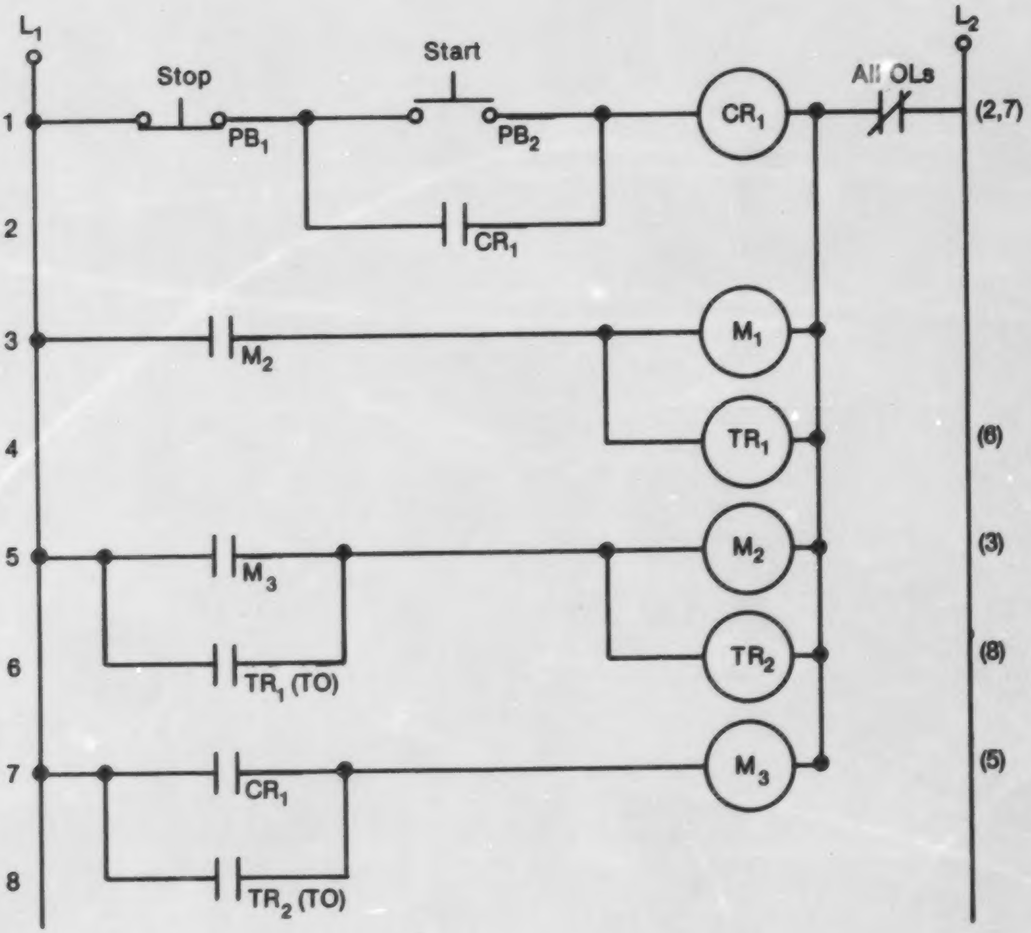

L1
L2
Stop
Start
PB1
PB2
CR1
All OLs
(2,5)
1
2
3
4
5
CR1
M2
M1
M3
M2
CR1
M3
(3)
(4)

1. Start

2. Stop

ASSIGNMENT SHEET #3

B.


L1
L2
Stop
Start
PB1
PB2
CR1
All OLs
(2,7)
CR1
M2
M1
TR1
(6)
M3
M2
(3)
TR1 (TO)
TR2
(8)
CR1
M3
(5)
TR2 (TO)
1
2
3
4
5
6
7
8

ASSIGNMENT SHEET #3

1. Start

2. Stop

AC MOTOR CONTROLS
UNIT VII

ASSIGNMENT SHEET #4 — USE TABLES TO SELECT PROPER OVERLOAD HEATER COILS FOR DIFFERENT STARTERS

NAME ____________________ SCORE __________

The proper selection of overload heater coils is vital for the protection of expensive motors. All manufacturers provide heater-element selection tables, which are usually placed on the inside of the heater-element cover. Close attention is warranted while reading the tables because the print is so small. Careful reading will help prevent improper selection of a heater coil for a particular starter and enclosure.

A. Using Table 2 and the specifications given below, select the proper overload heater coil by using NEMA size and full-load amperage to cross-reference heater-coil number.

NEMA Size	**Three-Phase** NEMA Enclosure	Motor FLA	**Thermal Units** Heater-Coil Number
.00	A 10	.37	1. __________
0	A 10	.265	2. __________
2	A 50	5.5	3. __________
4	A 10	28.2	4. __________
1	A 50	10.28	5. __________
1	A 10	12.28	6. __________

ASSIGNMENT SHEET #4

TABLE 2

THREE-PHASE ENCLOSED CAT. NOS. A10 & A50*

Size 00-0-1	Size 2	Size 3	Size 4	Heater-Coil No.
Heater-Coil Ampere Range				
.155 — .173	...	...	...	H1101
.174 — .195	...	...	...	H1102
.196 — .220	...	...	...	H1103
.221 — .247	...	...	...	H1104
.248 — .278	...	...	...	H1105
.279 — .310	...	...	...	H1106
.311 — .349	...	...	...	H1107
.350 — .391	...	...	...	H1108
.392 — .441	...	...	...	H1109
.442 — .495	...	...	...	H1110
.496 — .555	...	...	...	H1111
.556 — .624	...	...	...	H1112
.625 — .703	...	...	...	H1113
.704 — .795	...	...	...	H1114
.796 — .895	...	...	...	H1115
.896 — .999	...	...	...	H1116
1.00 — 1.12	...	...	...	H1117
1.13 — 1.25	...	...	...	H1018
1.26 — 1.41	...	...	...	H1019
1.42 — 1.58	...	...	...	H1020
1.59 — 1.77	...	...	...	H1021
1.78 — 1.96	...	...	...	H1022
1.97 — 2.17	...	...	...	H1023
2.18 — 2.44	...	...	...	H1024
2.45 — 2.72	...	...	...	H1025
2.73 — 3.04	...	...	...	H1026
3.05 — 3.38	...	...	...	H1066
3.39 — 3.73	...	...	...	H1027
3.74 — 4.18	3.86 — 4.31	...	...	H1028
4.19 — 4.63	4.32 — 4.77	...	...	H1029
4.64 — 5.15	4.78 — 5.31	...	...	H1030
5.16 — 5.68	5.32 — 5.90	...	...	H1031
5.69 — 6.30	5.91 — 6.55	...	...	H1032
6.31 — 7.05	6.56 — 7.33	...	...	H1033
7.06 — 7.76	7.34 — 8.15	8.24 — 9.19	...	H1034
7.77 — 8.63	8.16 — 9.00	9.20 — 10.1	...	H1035
8.64 — 9.51	9.01 — 10.1	10.2 — 11.3	...	H1036
9.52 — 10.5	10.2 — 11.2	11.4 — 12.7	...	H1037
10.6 — 11.8	11.3 — 12.5	12.8 — 14.1	...	H1038
11.9 — 13.1	12.6 — 13.9	14.2 — 15.8	...	H1039
13.2 — 14.8	14.0 — 15.7	15.9 — 17.7	...	H1040
14.9 — 16.7	15.8 — 17.5	17.8 — 20.1	...	H1041
16.8 — 18.9	17.6 — 19.8	20.2 — 22.7	20.6 — 23.3	H1042
19.0 — 21.3	19.9 — 22.3	22.8 — 25.5	23.4 — 26.0	H1043
21.4 — 24.1	22.4 — 25.4	25.6 — 28.9	26.1 — 30.5	H1044
24.2 — 27.0	25.5 — 28.7	29.0 — 32.5	30.6 — 33.6	H1045
...	28.8 — 32.5	32.6 — 36.7	33.7 — 37.9	H1046
...	32.6 — 36.6	36.8 — 41.0	38.0 — 42.9	H1047
...	36.7 — 41.0	41.1 — 46.0	43.0 — 48.2	H1048
...	41.1 — 45.0	46.1 — 51.8	48.3 — 54.6	H1049
...	...	51.9 — 58.6	54.7 — 61.2	H1050
...	...	58.7 — 64.6	61.3 — 67.6	H1051
...	...	64.7 — 72.7	67.7 — 75.9	H1052
...	...	72.8 — 83.1	76.0 — 87.1	H1054
...	...	83.2 — 90.0	87.2 — 97.5	H1055
...	...	...	97.6 — 109.0	H1056
...	...	...	110.0 — 122.0	H1057
...	...	...	123.0 — 135.0	H1058

Source: Eaton Corp., Cutler-Hammer Products.

ASSIGNMENT SHEET #4

B. Using Table 3 on the following page and the specifications given below, select the proper overload heater coil by using the number of phases and full-load amperage to cross-reference heater-coil number.

Square D Table for Starters of Class 8536
(In Own Enclosure)

Phase	Motor FLA	Thermal-Unit Number
Single phase	1.9	1. ______________________
Three phase	5.8	2. ______________________
Single phase	8.1	3. ______________________
Single phase	7.47	4. ______________________
Three phase	6.6	5. ______________________
Single phase	3.8	6. ______________________

ASSIGNMENT SHEET #4

TABLE 3

Size 00, Type A (Class 8536 Only)

Motor Full-Load Current		
Single Phase 1 Thermal Unit	Poly-phase 3 Thermal Units	Thermal Unit Number
0.42—0.46	0.38—0.40	A .49
0.47—0.50	0.41—0.44	A .54
0.51—0.55	0.45—0.49	A .59
0.56—0.62	0.50—0.55	A .65
0.63—0.67	0.56—0.60	A .71
0.68—0.73	0.61—0.65	A .78
0.74—0.81	0.66—0.72	A .86
0.82—0.89	0.73—0.79	A .95
0.90—0.98	0.80—0.88	A 1.02
0.99—1.12	0.89—0.98	A 1.16
1.13—1.20	0.99—1.07	A 1.25
1.21—1.34	1.08—1.17	A 1.39
1.35—1.41	1.18—1.25	A 1.54
1.42—1.51	1.26—1.33	A 1.63
1.52—1.62	1.34—1.44	A 1.75
1.63—1.73	1.45—1.53	A 1.86
1.74—1.86	1.54—1.65	A 1.99
1.87—2.02	1.66—1.79	A 2.15
2.03—2.25	1.80—1.99	A 2.31
2.26—2.46	2.00—2.18	A 2.57
2.47—2.77	2.19—2.45	A 2.81
2.78—2.99	2.46—2.65	A 3.61
3.00—3.26	2.66—2.90	A 3.95
3.27—3.59	2.91—3.19	A 4.32
3.60—3.99	3.20—3.56	A 4.79
4.00—4.42	3.57—3.83	A 5.30
4.43—4.61	3.84—4.08	A 5.78
4.62—5.23	4.09—4.64	A 6.20
5.24—5.39	4.65—5.00	A 6.99
5.40—5.88	5.01—5.36	A 7.65
5.89—6.56	5.37—5.87	A 8.38
6.57—7.18	5.88—6.43	A 9.25
7.19—7.80	6.44—6.79	A 9.85
7.81—9.00	6.80—7.00	A 11.00

Source: The Square D Company.

AC MOTOR CONTROLS
UNIT VII

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1. Instant operating with blowout
   2. Instant operating without blowout
   3. Energized timed
   4. Deenergized timed

B. 1. Thermal
   2. Magnetic

C. 1. Two position
   2. Three position

D. 1. Single-circuit momentary contact
   2. Double-circuit momentary contact
   3. Mushroom-head momentary contact
   4. Wobble-stick momentary contact
   5. Two single-circuit maintained contacts
   6. One double-circuit maintained contact
   7. Illuminated

E. 1. Wiring not connected
   2. Power wiring
   3. Wiring terminal
   4. Wiring connected
   5. Control wiring

ANSWERS TO ASSIGNMENT SHEETS

6. Ground
7. Mechanical connection
8. Mechanical interlock connection

F. 1. Single phase
2. Single-phase two speed
3. Three phase

G. 1. Single voltage
2. Dual voltage

H. Limit switches

I. Foot switches

J. Pressure and vacuum switches

K. Liquid-level switches

L. Temperature-actuated switches

M. Flow switches

N. Coil

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #2

A. Article 430-72

B.
  1. Conductors that do not leave enclosure
  2. Conductors supplied by transformer

C. No

D. Must be protected by raceway or enclosure

E. At the time the motor circuit is disconnected

F. A circuit designed for signaling and control of a motor starter

G. Conduit or raceway

Assignment Sheet #3

A.
  1. Start
     - a. Start button depressed
     - b. Energizes coil CR1
     - c. Closes contact CR1 (bypasses start button)
     - d. Closes contact CR1
     - e. Energizes operating coil M3
     - f. Closes contact M3
     - g. Energizes operating coil M2
     - h. Closes contact M2
     - i. Energizes operating coil M1

ANSWERS TO ASSIGNMENT SHEETS

2. Stop
   - a. Stop button depressed
   - b. Deenergizes coil CR1
   - c. Opens contact CR1
   - d. Opens contact CR1
   - e. Deenergizes operating coil M3
   - f. Opens contact M3
   - g. Deenergizes operating coil M2
   - h. Opens contact M2
   - i. Opens operating coil M1

   (NOTE: This leaves all coils deenergized and all contacts open except the stop switch.)

B. 1. Start
   - a. Start button depressed
   - b. Energizes coil CR1
   - c. Closes contact CR1 (bypasses start button)
   - d. Closes contact CR1
   - e. Energizes coil M3
   - f. Closes contact M3
   - g. Energizes coil TR2
   - h. Closes contact TR2
   - i. Energizes coil M2
   - j. Closes contact M2
   - k. Energizes coil TR1

ANSWERS TO ASSIGNMENT SHEETS

l. Closes contact TR1 (TO)

m. Energizes coil M1

(NOTE: This leaves all contacts except the start switch closed and motor operating.)

2. Stop

   a. Stop button depressed

   b. Deenergizes coil CR1

   c. Opens contact CR1

   d. Opens contact CR1

   (NOTE: Motors continue to operate with both timed relays energized, holding the TR [TO] contacts closed, which reveals that the scheme of energizing and deenergizing needs to be modified.)

Assignment Sheet #4

A. 1. H 1108

2. H 1105

3. H 1031

4. H 1044

5. H 1037

6. H 1039

B. 1. A 2.15

2. A 8.38

3. A 11.0

4. A 9.85

5. A 9.85

6. A 4.79

AC MOTOR CONTROLS
UNIT VII

JOB SHEET #1 — CHANGE THERMAL OVERLOADS

I. Equipment and materials

- A. Motor with starter
- B. Screwdriver
- C. Multimeter
- D. Needle-nosed pliers
- E. Thermal overloads (type and size recommended in service manual)
- F. Motor tagout
- G. Service manual for starter

II. Procedure

- A. Deenergize circuit to starter; check open and lock
- B. Check line leads L1, L2, and L3 for voltage

  (NOTE: If you have a low-voltage control circuit, it must be deenergized.)
- C. Check control circuit for voltage
- D. Remove thermal overload devices to be replaced
- E. Replace thermal overloads with new ones of correct size
- F. Check all connections for tightness
- G. Energize circuit for testing
- H. Energize starter; start motor to check operations

  (NOTE: Show work to instructor for evaluation and comments.)
- I. Deenergize motor circuit; check open and lock
- J. Clean work area; return equipment and materials to their proper places

AC MOTOR CONTROLS
UNIT VII

JOB SHEET #2 — REWIRE A REVERSING STARTER

I. Equipment and materials

A. Three-phase motor

B. Three-phase reversing motor starter

C. Wire suitable for carrying motor full-load amperage

D. Insulated wire for controls

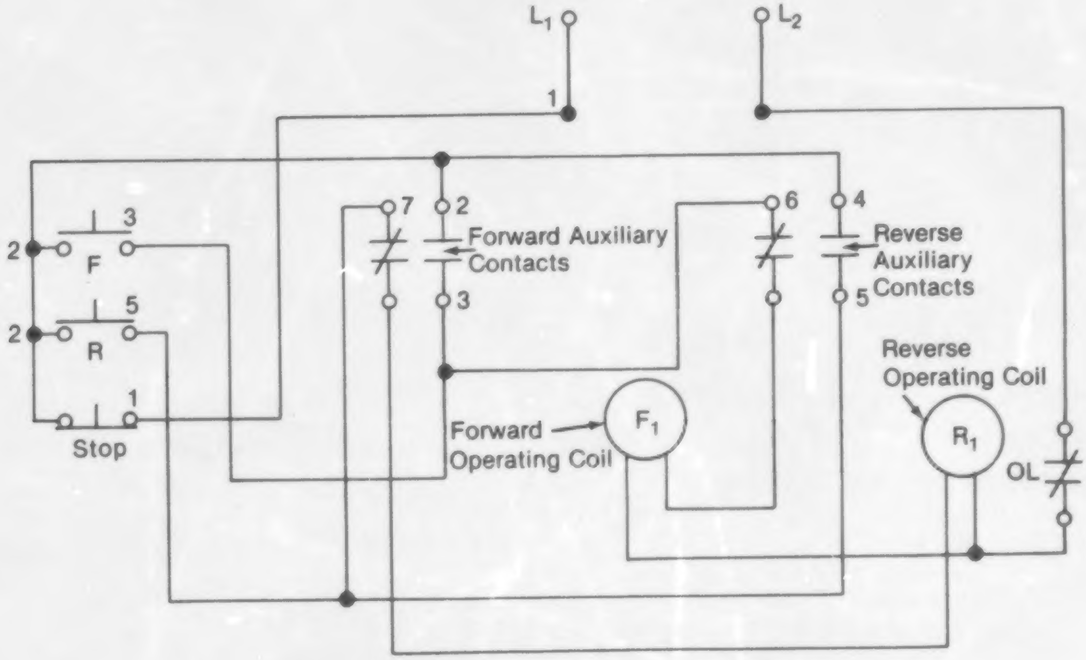
E. Pouch tools

F. Forward/reverse/stop control station

G. Power supply with proper voltage for motor and operating coils

II. Procedure for rewiring starter (Figure 32)

FIGURE 32


L_1
L_2
1
2
3
F
2
5
R
1
Stop
7
2
Forward Auxiliary Contacts
3
6
4
Reverse Auxiliary Contacts
5
Reverse Operating Coil
Forward Operating Coil
F_1
R_1
OL

JOB SHEET #2

A. Remove any existing wiring on starter and remote-control station

B. Wire control wire from L2 to overload terminals, then to one side of both forward and reverse operating coils

(CAUTION: Do not get L2 wire mixed up with L1 wires and the control station.)

C. Install connection from #1 L1 to terminal #1 on remote station

D. Install wiring from control station #2 (with jumpers) to auxiliary contact terminals #2 and #4

E. Install control wire from control station #3 to auxiliary contact terminal #3; from #3, extend wire to terminal #6, and then from other end of that auxiliary contact to empty terminal on forward operating coil

F. Install control wire from control station terminal #5 to auxiliary contact #7 and onward to auxiliary contact terminal #5

G. Connect wire from other end of auxiliary contact #7 to empty terminal on reverse operating coil

(NOTE: Show work to instructor for evaluation and comments.)

H. Apply power to L1 and L2

I. Push forward button

(NOTE: Forward contact should close; reversing contact should remain open.)

J. Push stop button; observe

K. Push reverse button; observe

L. Push stop button; observe

(NOTE: Reverse contact should drop open.)

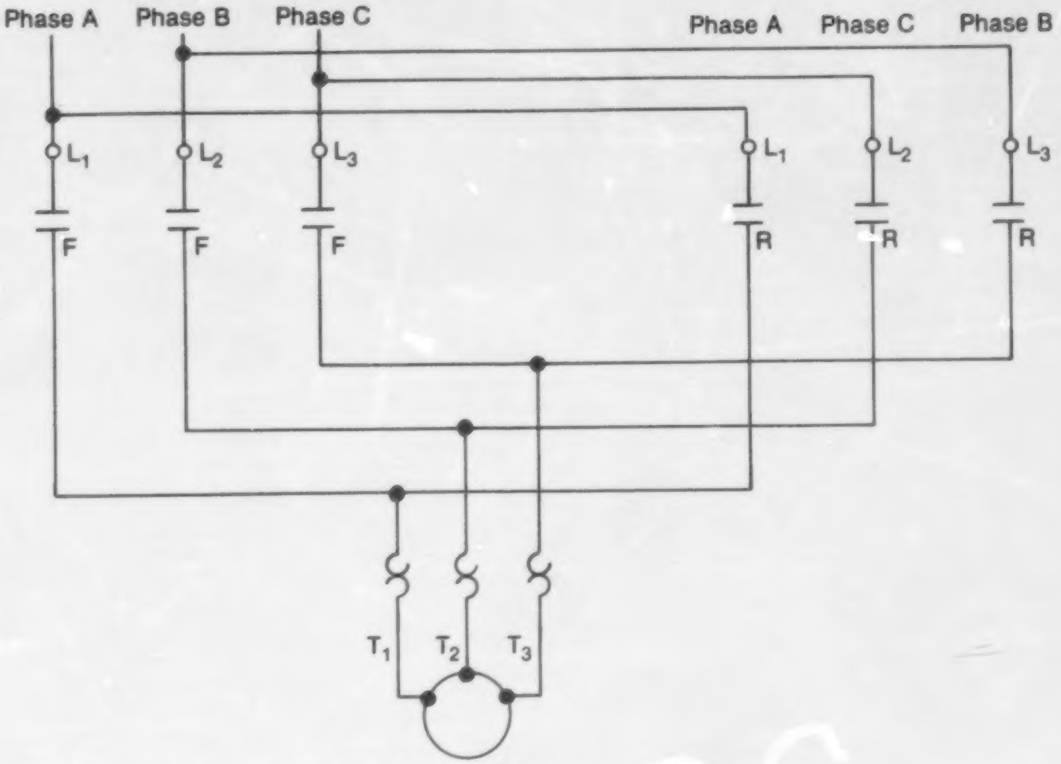
M. Open and lock open power supply switch

(NOTE: If the reversing contact did not operate correctly, double check connections [possibly a wire slipped off a terminal]. If no error is found, remove wiring and repeat steps B through H, one step at a time; then repeat tests.)

JOB SHEET #2

III. Procedure for rewiring power (Figure 33)

FIGURE 33


Phase A
Phase B
Phase C
Phase A
Phase C
Phase B
L_1
L_2
L_3
L_1
L_2
L_3
F
F
F
R
R
R
T_1
T_2
T_3

A. Connect motor lead T1 to starter terminal T1

(NOTE: Make good connections.)

B. Connect motor lead T2 to starter terminal T2

C. Connect motor lead T3 to starter terminal T3

D. Connect A phase line to L1 on both contacts

E. Connect B phase line to L2 on forward contact and L3 on reverse contact

F. Connect C phase line to L3 on forward contact and L2 on reversing contact

G. Connect phase lines A, B, and C to power supply switch

(NOTE: Show work to instructor for evaluation and safety before closing power supply switch.)

JOB SHEET #2

H. Close power supply switch

I. Press forward button; observe

J. Press stop button; observe

K. Press reverse button; observe

L. Press stop button; observe

(NOTE: Forward and reverse contacts should pull in and drop out as their respective buttons are pushed.)

M. Open and lock power supply switch

N. Disassemble circuit; clean work area and store equipment and materials properly

AC MOTOR CONTROLS
UNIT VII

JOB SHEET #3 — DIAGRAM AND WIRE A NONREVERSING MOTOR STARTER WITH ONE START/STOP STATION

I. Equipment and materials

A. Voltmeter

B. Screwdriver

C. Wire strippers

D. Needle-nosed pliers

E. Start/stop buttons

F. Nonreversing motor starter with one start/stop station

G. Power supply with proper voltage for coil

H. Control wire, #14

II. Preparation for procedure

A. On a separate sheet of paper, draw a wiring diagram for a motor starter with one start/stop station

B. Have instructor check your diagram

III. Procedure

A. Deenergize circuit to starter and lock switch open

B. Check line leads for voltage

C. Install wire from L1 to terminal #1 on stop button

D. Install wire from terminal #2 on starter to terminal #2 on stop button

E. Install wire from terminal #3 on starter to terminal #3 on start button

(NOTE: Have instructor evaluate work before proceeding.)

F. Turn on power to starter

G. Press start button (starter should pull in and hold)

H. Press stop button (starter should drop out and stay out)

I. Disconnect power and lock open

J. Remove wiring from starter and start/stop buttons

K. Clean work area; return equipment and materials to their proper places

AC MOTOR CONTROLS
UNIT VII

TEST

NAME ____ SCORE ________________

1. Match to their correct definitions terms associated with alternating-current motor controls. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

______a. Method of motor starting that connects motor directly to supply line

______b. Pertaining to self-acting starter completely controlled by pilot switches or some other sensing device

______c. Contact provided in addition to the main circuit contacts but operated with the main contacts

______d. Two different metals bonded to provide fast heat transfer to trip contacts by mechanical deflection

______e. Device without overload protection; repeatedly establishes or interrupts an electric power circuit

______f. Magnetic coil used to operate a relay, contactor, or starter

______g. Light used to indicate circuit status

______h. Momentarily operating; moving a driven machine a small distance

______i. Function of magnetic control that releases contactor upon low voltage and requires manual restarting

______j. Function of magnetic control that releases contactor upon low voltage and automatically restarts when voltage is restored

______k. Contactor operated electromechanically

______l. Starter designed to start a motor at a reduced speed and build to full speed in preset steps

1. Low-voltage protection (LVP)
2. Pilot light
3. Automatic starting
4. Solenoid
5. Across-the-line
6. Magnetic contactor
7. Auxiliary contact
8. Multispeed starter
9. Bimetal
10. Jogging (inching)
11. Contactor
12. Low-voltage release (LVR)

TEST

______m. Device for protecting a motor from overload current or voltage

______n. Braking by reverse line voltage or phase sequence of motor

______o. Switch, manually operable plunger, button, or actuating device

______p. Device that applies reduced voltage to motor during starting

______q. Electromechanical device operated by a coil; uses contacts to make or break control circuits

______r. Device that controls electrical apparatus from some distance

______s. Manually operated multiposition switch

______t. Control device with electric contactor with overload protection; designed to protect motor from voltage inrush during starting

______u. Schematic consisting of symbols and lines that indicate power source and how current flows through various parts of a control circuit

______v. Schematic consisting of symbols and lines that indicate all connections and placement of all component parts in a device or circuit, including the power-circuit wiring

______w. Circuit that controls some function of a motor or device; carries performance signals

______x. Pilot device that delays closing or opening of a circuit for a specific time; may be motor-driven, solenoid-actuated, or electronic

______y. Sequence of steps required to perform a specific function: signal, decision, actions

13. Control logic
14. Push button
15. Plugging
16. Overload relay
17. Reduced-voltage starter
18. Remote control
19. Control circuit
20. Relay
21. Selector switch
22. Timer
23. Starter
24. Line diagram (ladder diagram)
25. Wiring diagram

TEST

2. Match common wiring and control symbols to their correct names. Write the correct numbers in the blanks. Symbols are continued on the next page.

______a. Pressure and vacuum switch

______b. Single-circuit momentary-contact push button

______c. Double-circuit momentary-contact push button

______d. Two-position selector (X-contacts closed)

______e. Limit switch

______f. Energized timed contact

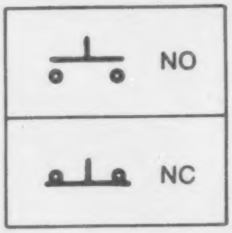
______g. Liquid-level switch

______h. Temperature-actuated switch

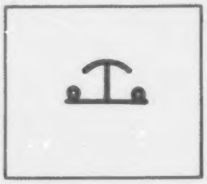
______i. Deenergized timed contact

______j. Mushroom-head momentary-contact push button

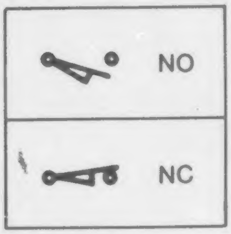
1.



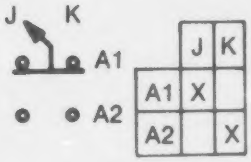
2.



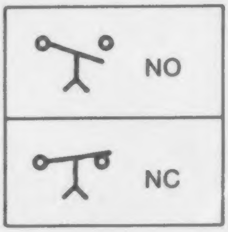
3.



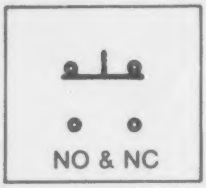
4.



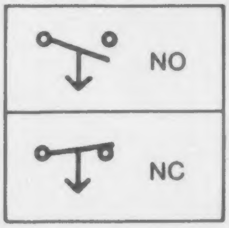
5.



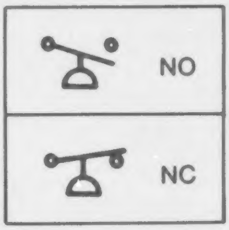
6.



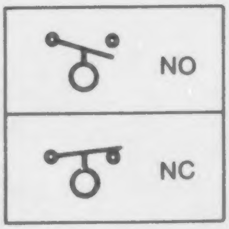
7.



8.

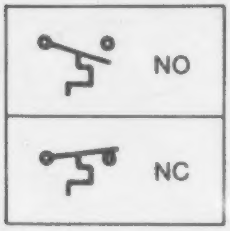


9.



TEST

10.



3. Describe types of controllers.

a. Manual — ______________________________

____

b. Semiautomatic — ______________________________

____

c. Automatic — ______________________________

____

4. Name major headings for control circuits from *National Electrical Code*.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

TEST

5. Match horsepower ratings to correct National Electrical Manufacturers Association (NEMA) industrial motor starters. Write the correct numbers in the blanks.

_____a. Size 1
_____b. Size 0
_____c. Size 00
_____d. Size 3
_____e. Size 4
_____f. Size 2

1. 10 horsepower at 460 volts
2. 50 horsepower at 460 volts
3. 25 horsepower at 460 volts
4. 2 horsepower at 460 volts
5. 100 horsepower at 460 volts
6. 5 horsepower at 460 volts

6. Match National Electrical Manufacturers Association (NEMA) motor-starter enclosures to their correct uses. Write the correct numbers in the blanks.

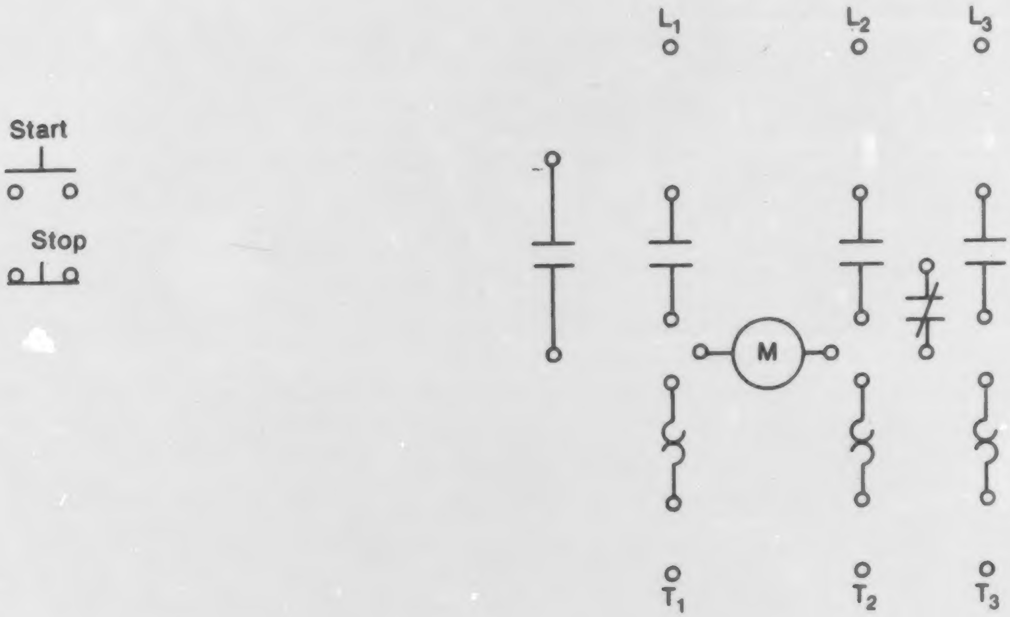
_____a. Intended for use indoors or outdoors where windblown dust, rain, or hose-directed water is present
_____b. Intended for use indoors in hazardous locations where Class II, Groups E, F, or G conditions exist
_____c. Intended for use outdoors where rain and sleet are present
_____d. Intended for use indoors in hazardous locations where Class I, Group C or D conditions exist
_____e. Intended for indoor use
_____f. Intended for use in corrosive or chemical atmospheres

1. NEMA Type 4X
2. NEMA Type 7
3. NEMA Type 9
4. NEMA Type 1
5. NEMA Type 3R
6. NEMA Type 4

TEST

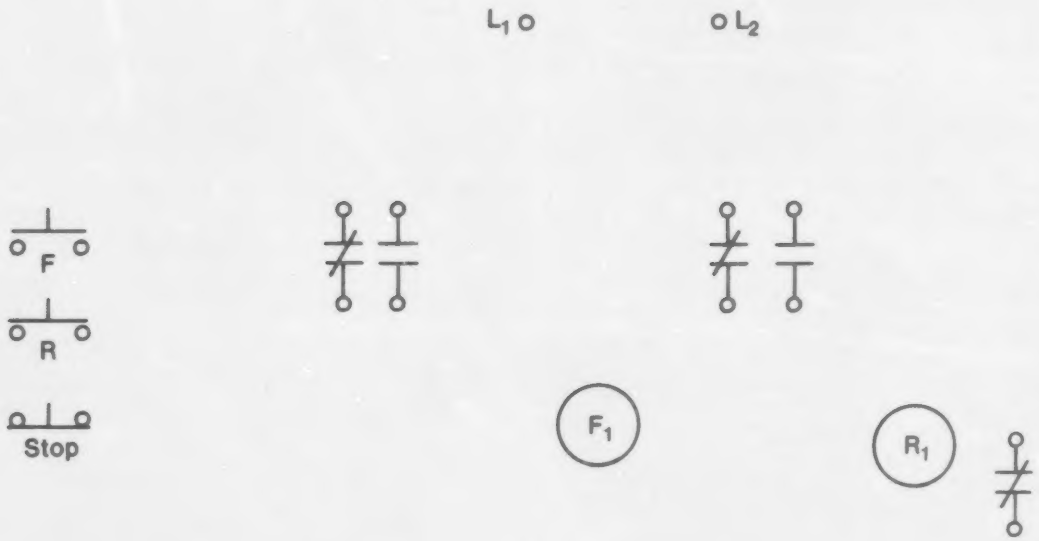
7. Complete the following wiring diagrams of alternating-current motor starters.

a. Three-phase nonreversing with remote start/stop station


Start
Stop
L1
L2
L3
M
T1
T2
T3

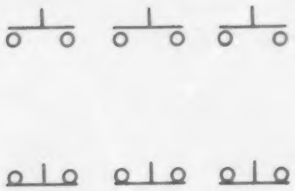
TEST

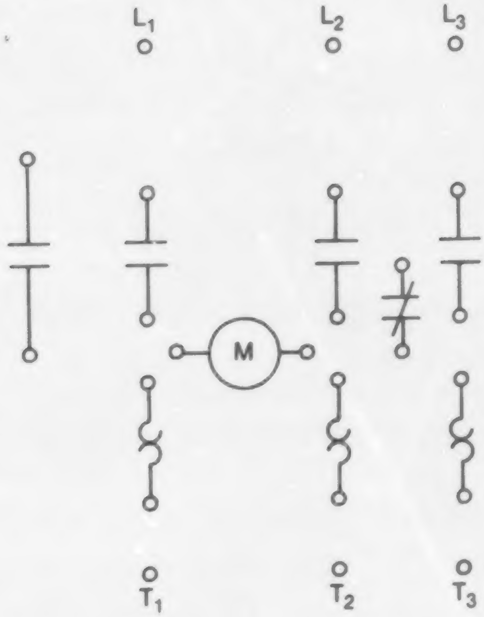
b. Reversing starter with remote forward/reverse stop station


L_1
L_2
F
R
Stop
F_1
R_1

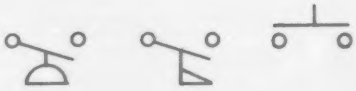
TEST

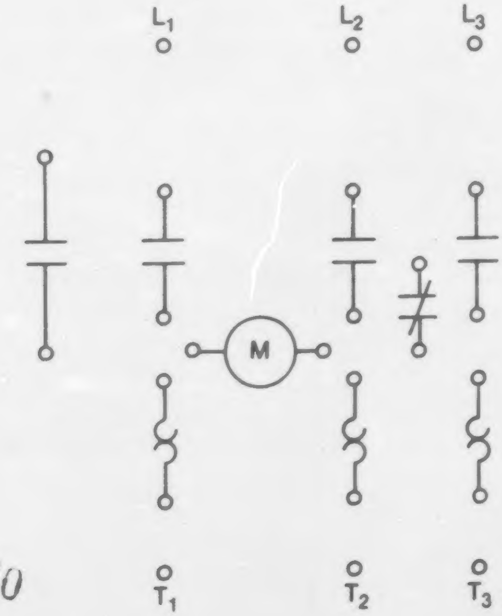
c. Multiple remote start/stop stations




L1
L2
L3
M
T1
T2
T3

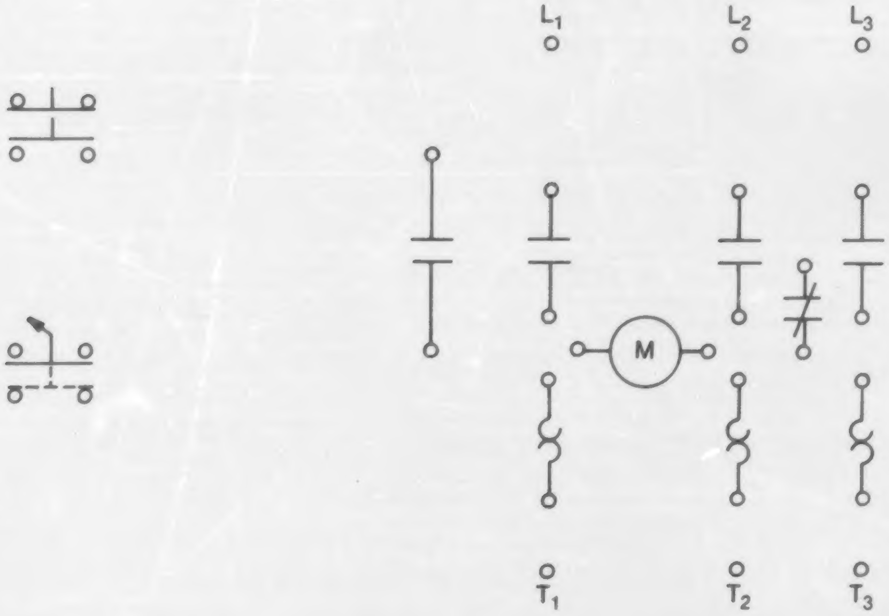
d. Pump circuit with pressure and flow switches acting as stop switches



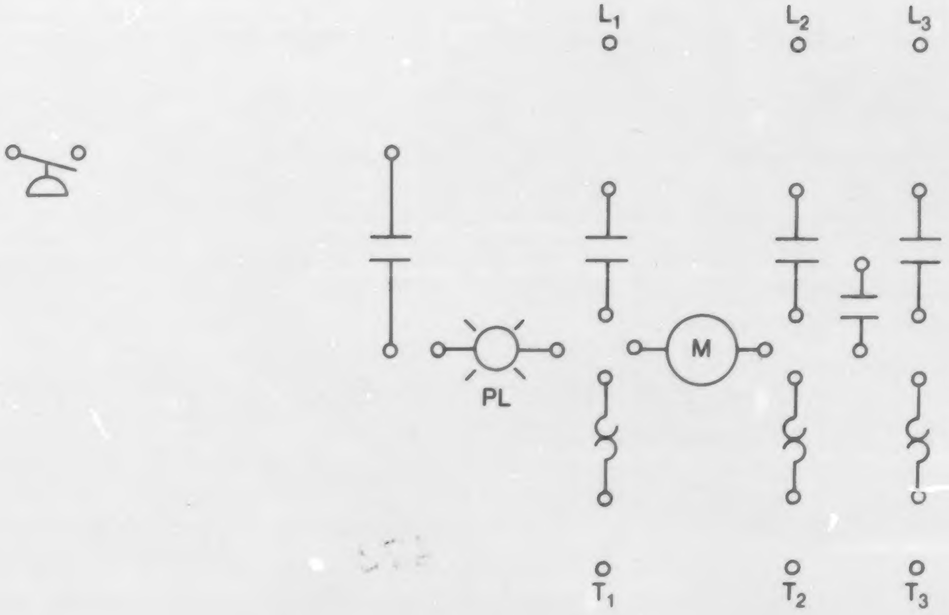

L1
L2
L3
M
T1
T2
T3

TEST

e. Start/stop circuit with selector switch for jogging motor

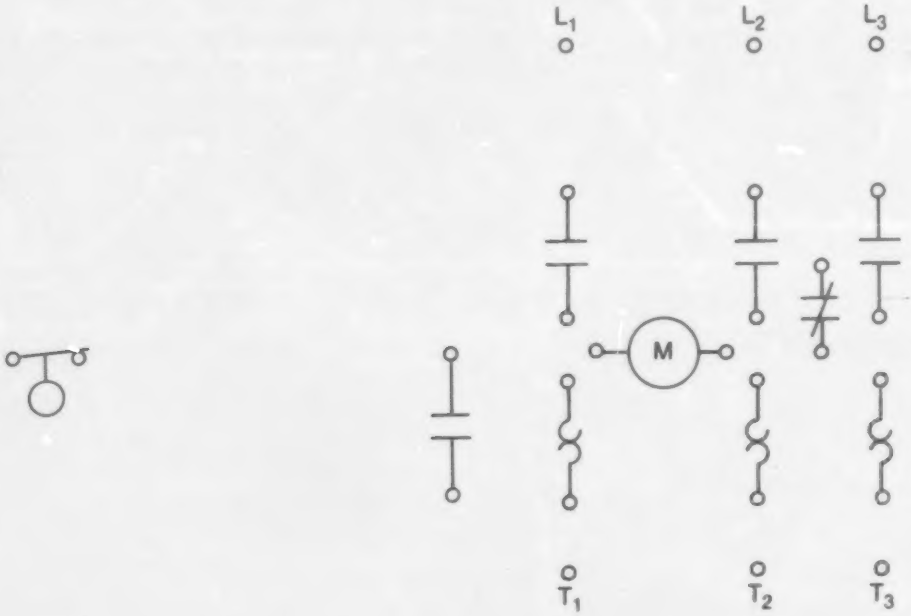

L_1
L_2
L_3
M
T_1
T_2
T_3

f. Typical control circuit for an air compressor with pilot light


L_1
L_2
L_3
PL
M
T_1
T_2
T_3

TEST

g. Motor starter with float switch as start/stop; no holding contacts



(NOTE: Test questions 8-11 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

8. Use *National Electrical Code* to answer questions about motor control circuits.

9. Determine sequence of operations from ladder diagrams.

10. Use tables to select proper overload heater coils for different starters.

11. Demonstrate the ability to

    a. Change thermal overloads.

    b. Rewire a reversing starter.

    c. Diagram and wire a nonreversing motor starter with one start/stop station.

AC MOTOR CONTROLS
UNIT VII

ANSWERS TO TEST

1.	a.	5	h.	10	o.	14	v.	25
	b.	3	i.	1	p.	17	w.	19
	c.	7	j.	12	q.	20	x.	22
	d.	9	k.	6	r.	18	y.	13
	e.	11	l.	8	s.	21		
	f.	4	m.	16	t.	23		
	g.	2	n.	15	u.	24		

2.	a.	8	f.	5
	b.	1	g.	9
	c.	6	h.	10
	d.	4	i.	7
	e.	3	j.	2

3. Description should include the following

   a. Manual — Starters operated by hand

   b. Semiautomatic — Starters controlled by manual pilot switches, push-button switches, drum switches, or similar equipment

   c. Automatic — Starters activated by sensing devices, float switches, limit switches, temperature-controlled contacts, or similar devices

4. a. Definition of motor control circuit

   b. Overcurrent protection

   c. Conductor protection

   d. Control circuit transformer

   e. Mechanical protection of conductor

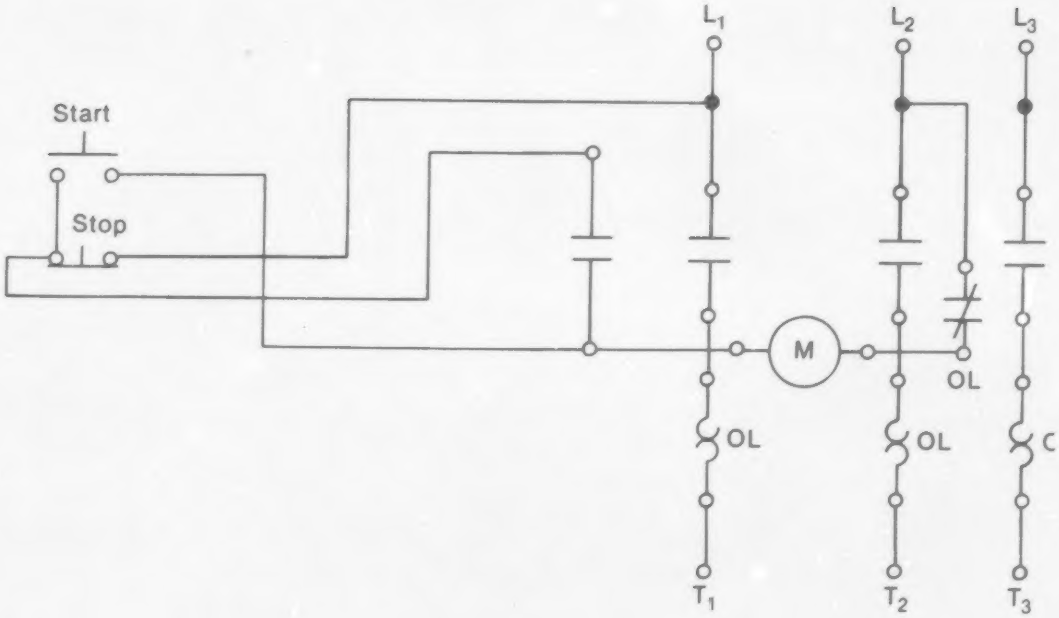
   f. Disconnection of control circuit

   g. Control transformer in controller

ANSWERS TO TEST

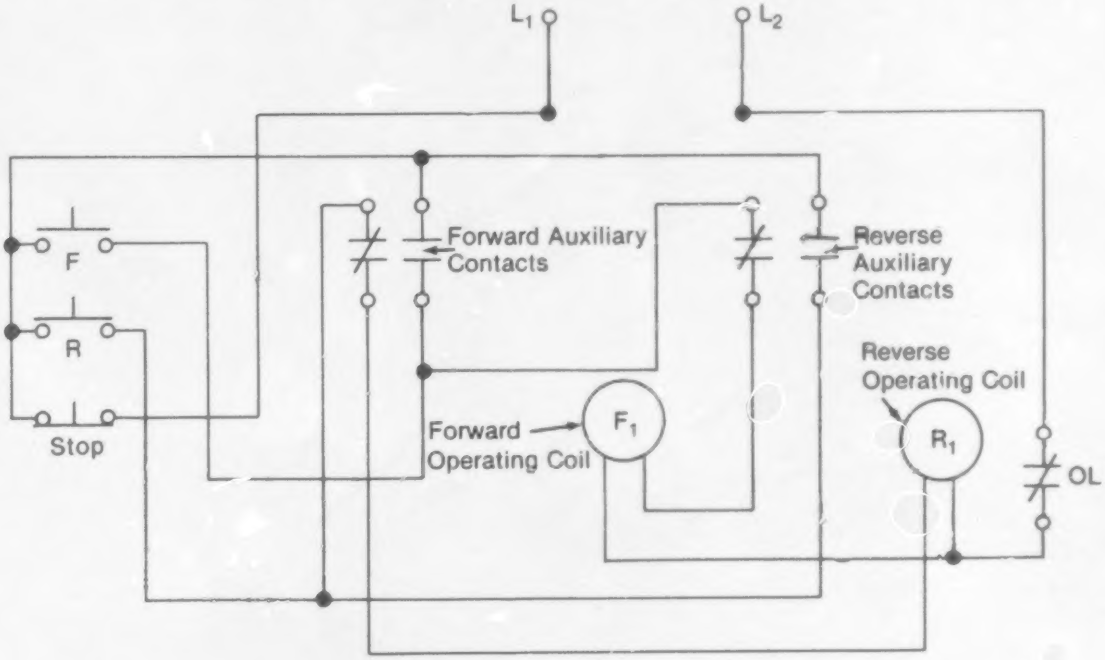
5.	a.	1	d.	2
	b.	6	e.	5
	c.	4	f.	3
6.	a.	6	d.	2
	b.	3	e.	4
	c.	5	f.	1

7. a. Three-phase nonreversing with remote start/stop station

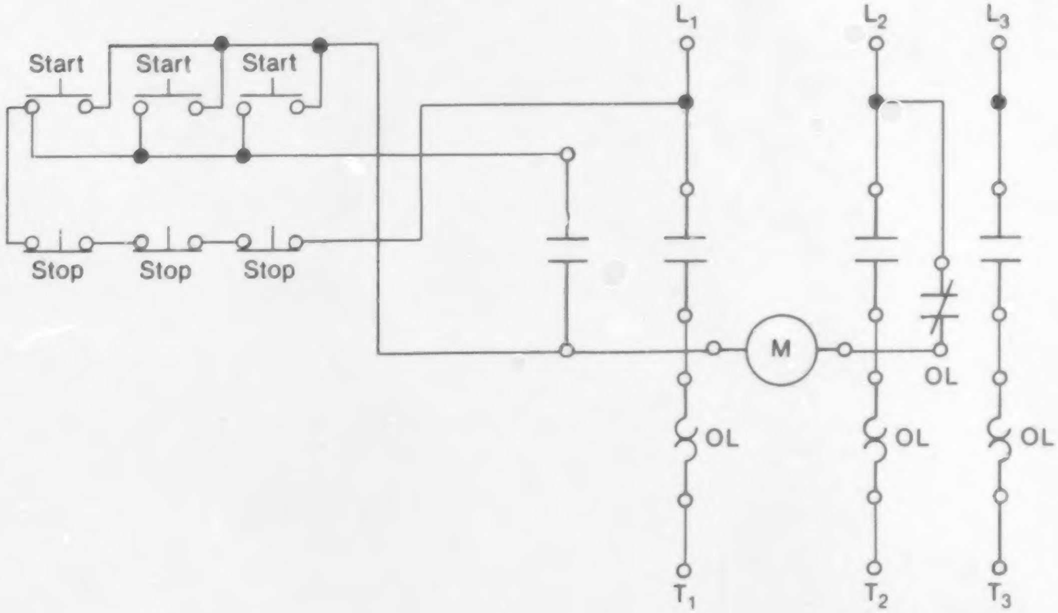

L$_1$
L$_2$
L$_3$
Start
Stop
M
OL
OL
OL
C
T$_1$
T$_2$
T$_3$

ANSWERS TO TEST

b. Reversing starter with remote forward/reverse stop station

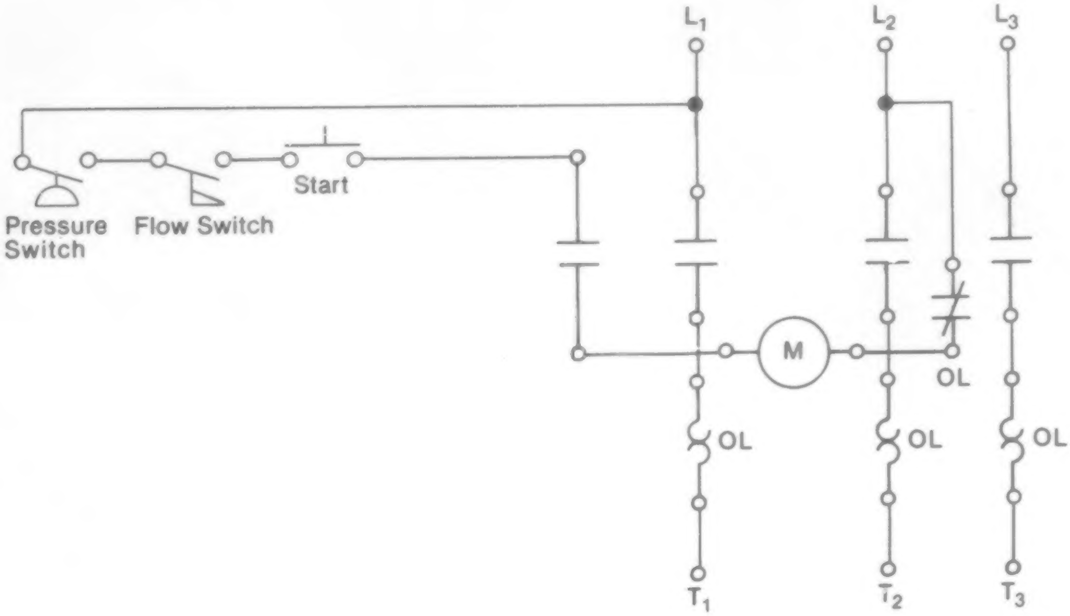

L1
L2
F
R
Stop
Forward Auxiliary Contacts
Reverse Auxiliary Contacts
Reverse Operating Coil
Forward Operating Coil
F1
R1
OL

c. Multiple remote start/stop stations

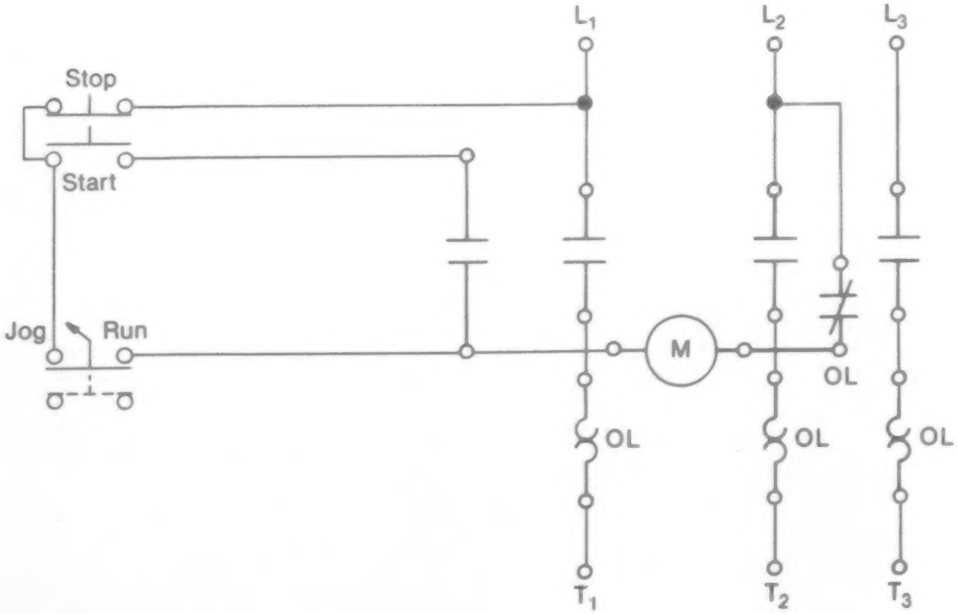

Start
Start
Start
Stop
Stop
Stop
L1
L2
L3
M
OL
OL
OL
OL
T1
T2
T3

ANSWERS TO TEST

d. Pump circuit with pressure and flow switches acting as stop switches

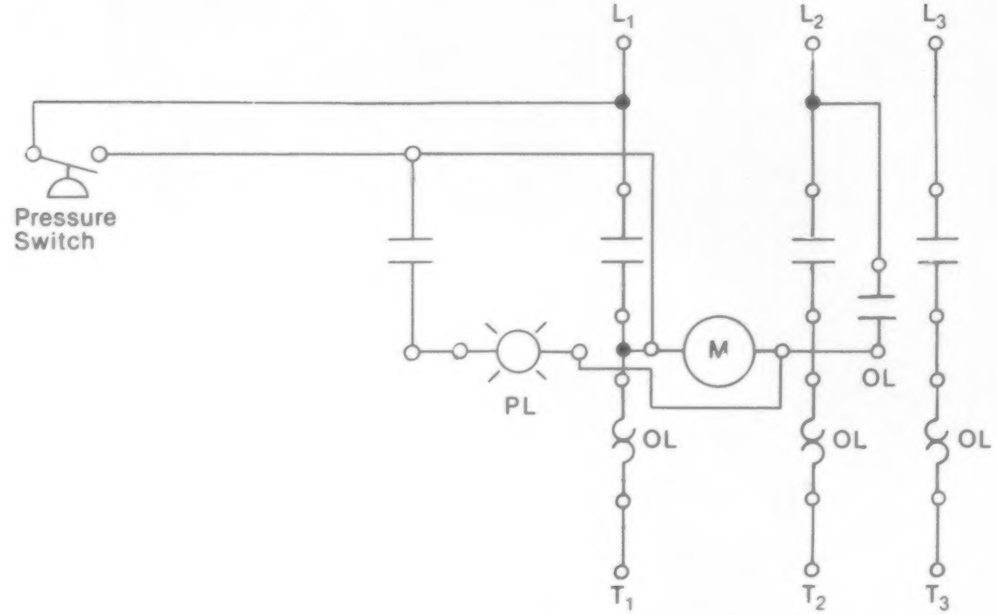

L1
L2
L3
Start
Pressure Switch
Flow Switch
M
OL
OL
OL
OL
T1
T2
T3

e. Start/stop circuit with selector switch for jogging motor

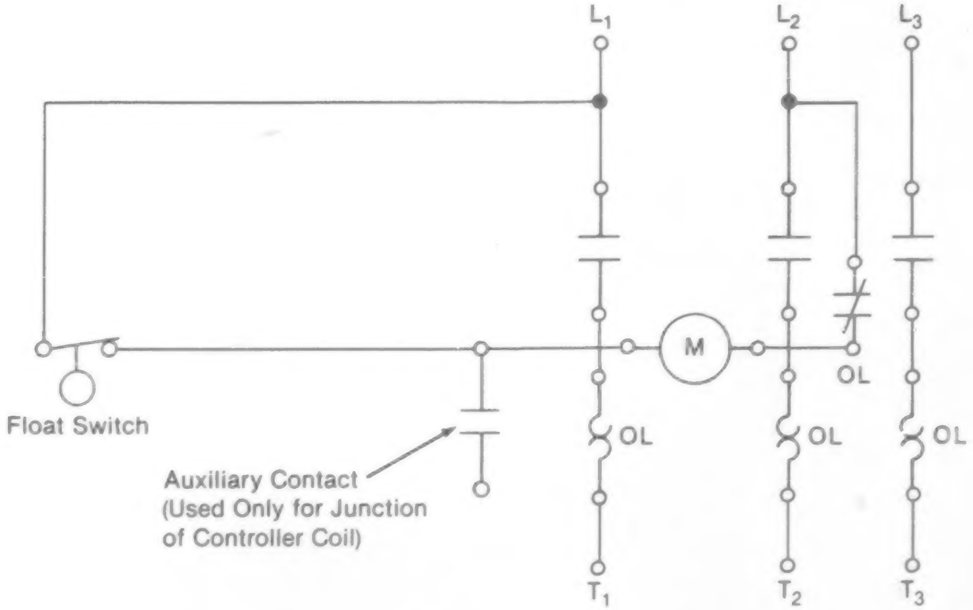

L1
L2
L3
Stop
Start
Jog
Run
M
OL
OL
OL
OL
T1
T2
T3

ANSWERS TO TEST

f. Typical control circuit for an air compressor with pilot light


L1
L2
L3
Pressure Switch
PL
M
OL
OL
OL
OL
T1
T2
T3

g. Motor starter with float switch as start/stop; no holding contacts


L1
L2
L3
Float Switch
M
OL
OL
OL
OL
Auxiliary Contact (Used Only for Junction of Controller Coil)
T1
T2
T3

ANSWERS TO TEST

8. Evaluated to the satisfaction of the instructor

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor

MOTOR GENERATORS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to inspect and make minor repairs on a motor generator. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with motor generators to their correct definitions.
2. Label the principal parts of a motor generator.
3. Name uses of motor generators.
4. Name functions of motor generators.
5. Select from a list guidelines for lubricating bearings properly.
6. Select from a list guidelines for proper care of commutators.
7. List items to check when inspecting brushes.
8. Arrange in order procedures for cleaning insulation.
9. Complete weekly inspection of motor generator.
10. Complete six- and twelve-month inspections of motor generator.
11. Demonstrate the ability to supervise the repair of an uneven commutator.

MOTOR GENERATORS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Obtain a classroom copy of *Electrical Maintenance Hints*, available from WESCO (Westinghouse Electric Supply Co.), Westinghouse Building, Gateway Center, Pittsburgh, Pennsylvania 15222, 412-255-3800.

B. Provide students with objective sheet.

C. Discuss unit and specific objectives. Point out the importance of each area in servicing a motor generator.

D. Provide students with information, assignment, and job sheets.

E. Discuss information, assignment, and job sheets.

1. Discuss terms and definitions, using Information Sheet, Section I, as well as a partially disassembled motor generator for visual identification.

2. Point out the principal parts of a motor generator, using Information Sheet, Section II and the partially disassembled generator.

3. Discuss the uses and functions of motor generators, using Information Sheet, Sections III and IV. A trip to a local computer firm may help the student realize the need for motor generators in large computer installations.

4. Discuss proper maintenance and inspection procedures, using Information Sheet, Sections V-VIII, Assignment Sheets #1 and #2, and Job Sheet #1. Stress the importance of scheduled maintenance checks on this type of equipment.

(NOTE: Refer students to Job Sheets #1-#7 in Unit I, "DC Motors.")

F. Give test.

G. Reteach and retest if necessary.

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

SUGGESTED ACTIVITIES

D. Assignment sheets

   1. Assignment Sheet #1 — Complete Weekly Inspection of Motor Generator

   2. Assignment Sheet #2 — Complete Six- and Twelve-Month Inspections of Motor Generator

E. Answers to assignment sheets

F. Job Sheet #1 — Supervise the Repair of an Uneven Commutator

G. Test

H. Answers to test

III. Unit references

A. Croft, Terrill, et al *American Electrician's Handbook*. New York: McGraw-Hill, 1980.

B. *Electrical Maintenance Hints*. Trafford, Pennsylvania: Westinghouse Electric Corporation, Printing Division, 1974.

MOTOR GENERATORS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Instruction book or leaflet — Data and instructions furnished by manufacturer with each piece of equipment; best source of information about a piece of equipment

B. Commutator — Copper bar segments on which brushes ride

C. Brushes — Graphite or carbon blocks that ride on surface of commutator to pick up energy generated by generator

D. Brush holder or brush rigging — Insulated mechanical holder and supports for graphite or carbon brushes

E. Mica — Insulation between each commutator segment and those adjacent to it

F. Mica undercutting — Process of cutting mica insulation to a depth of approximately 1/16 inch below face of commutator segments

G. Handstone — Abrasive stone used to dress or refinish commutator surface

H. Oil ring — Ring located around generator or motor shaft in sleeve bearing housing; used to pick up oil from lower pool of oil and carry it to top of shaft and bearing

I. Armature — Rotating part of a generator or motor

J. Stator — Stationary part of a generator or motor

K. Field coils — Stationary coils fastened to stator

INFORMATION SHEET

II. Principal motor generator parts (Figures 1 and 2)

FIGURE 1

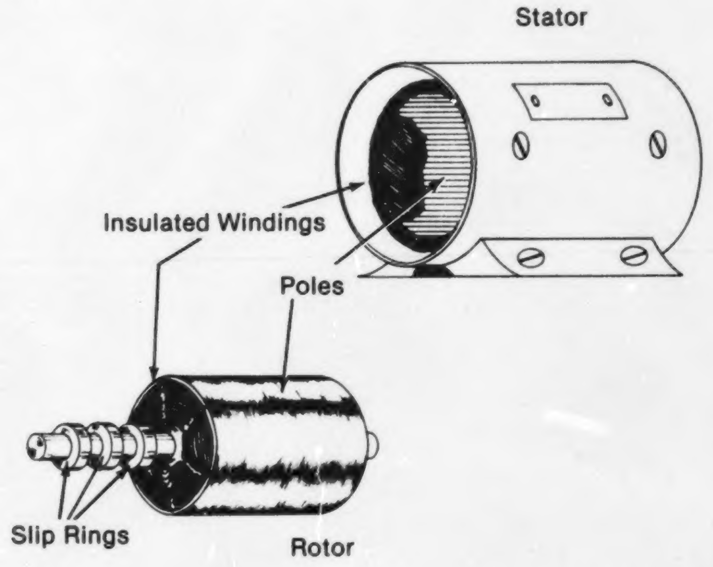
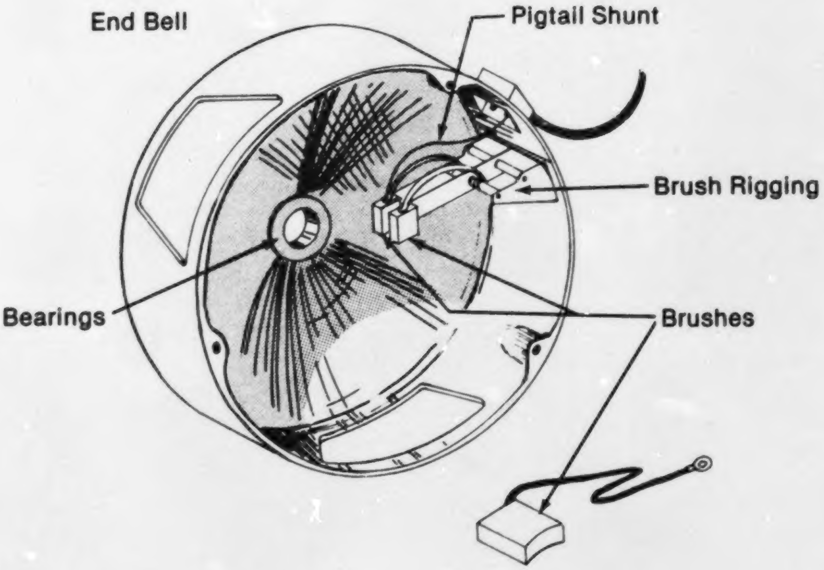

Stator
Insulated Windings
Poles
Slip Rings
Rotor

FIGURE 2


End Bell
Pigtail Shunt
Brush Rigging
Bearings
Brushes

INFORMATION SHEET

III. Uses of motor generators

   A. Electronic equipment

   B. Computer rooms

   C. Radio rooms

   D. Isolation of power from electrical system

IV. Functions of motor generators

   A. Stabilizing power

   B. Isolating equipment from electrical system

   C. Removing harmonic disturbances

   D. Removing transient voltage spikes

   E. Providing brownout protection

V. Guidelines for lubricating bearings properly

   A. Use lubricant specified by manufacturer if possible

   B. Cover unused portion of lubricant to protect from dirt, dust, and other contaminants

   C. Provide enough lubricant in bearings to cover start-up

   (NOTE: Provide adequate lubrication, but *do not overlubricate*; more motors fail due to too much lubricant than to too little lubricant.)

   D. Check for free movement of shaft and adequate end play

   (NOTE: Adequate end play is specified by manufacturer. It is usually $^1/_{16}$ to $^1/_8$ inch.)

VI. Guidelines for proper care of commutators (Job Sheet #1)

   A. Make periodic inspections to detect discoloration or any other defects

   (NOTE: One person should make all inspections. A different person may not detect gradual changes.)

   B. Keep all oil off commutator

   C. Keep commutator smooth and round

INFORMATION SHEET

VII. Checks to make when inspecting brush assembly (Assignment Sheets #1 and #2)

A. Brushes

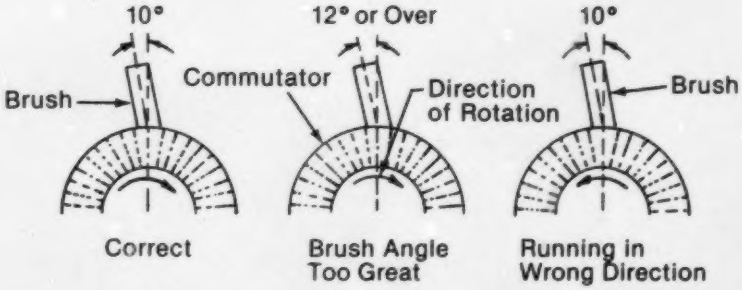
1. Move freely in holder
2. Not worn
3. Do not chatter

   (NOTE: Brush chattering is generally caused by high friction between brush and commutator surface.)

4. Have proper setting

   EXAMPLE:

FIGURE 3


10°
12° or Over
10°
Brush
Commutator
Direction of Rotation
Brush
Correct
Brush Angle Too Great
Running in Wrong Direction

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B. Brush faces have no embedded copper chips

C. Pigtail shunts are properly attached to brushes and holders

D. Spring has proper tension

(NOTE: Spring tension must be maintained as brushes wear down.)

VIII. Procedures for cleaning insulation

A. Clean with a vacuum cleaner

(NOTE: Do not use compressed air on insulation. Compressed air generally contains droplets of water, and the high pressure can easily damage insulation.)

B. Clean greasy surfaces with approved petroleum solvents

EXAMPLE: Stoddard solvent

INFORMATION SHEET

C. Apply coat of insulating paint if indicated

EXAMPLE: Red glyptal

D. Dry insulation thoroughly before testing or returning to service

E. Clean air circulation passages

(NOTE: Use compressed air on air circulation passages.)

F. Test insulation with megohmmeter

(NOTE: The minimum acceptable megohm reading should equal voltage divided by kilovolt amperes times 100, plus 1,000 $\left[M\Omega = \frac{V}{(kVA \times 100) + 1000}\right]$ The actual megohm reading is generally much higher.)

MOTOR GENERATORS
UNIT I

ASSIGNMENT SHEET #1 — COMPLETE WEEKLY INSPECTION OF MOTOR GENERATOR

NAME ____________________ SCORE ____________

Weekly inspections of motor generators are necessary to prevent minor problems from developing into serious problems.

Complete the inspection as outlined below and return to instructor.

A. Check components

	YES	NO
1. Commutator		
a. Discolored	____	____
b. Uneven	____	____
c. Signs of arcing	____	____
d. Dirty slots	____	____
2. Brushes		
a. Space between brush and commutator	____	____
b. Frayed or broken pigtail shunts	____	____
c. Cracked or broken brushes	____	____
d. Loose brush rigging	____	____
3. Oil level — Lower than designated level	____	____
4. Oil ring		
a. Seized	____	____
b. Turns with shaft	____	____
5. Shaft		
a. Oil or grease at DC end	____	____
b. Oil or grease at AC end	____	____

ASSIGNMENT SHEET #1

B. Check electrical controls

	YES	NO
1. Starter		
a. Discolored	____	____
b. Loose connections	____	____
c. Other defects	____	____
2. Fuse disconnect		
a. Discolored fuse clips	____	____
b. Loose connections	____	____
c. Other defects	____	____

C. Start motor generator

1. Record nameplate identification number________________________
2. Record actual speed (rpm)________________________
3. Record time to reach normal speed (rpm)________________________
4. Record nameplate full-load amperes (FLA)________________________
5. Check clamp-on ammeter readings

   Phase A ________________________

   Phase B ________________________

   Phase C ________________________

6. Record any other observations________________________

   ____

   ____

   (NOTE: Return completed inspection report to instructor for evaluation and comments.)

MOTOR GENERATORS
UNIT I

ASSIGNMENT SHEET #2 — COMPLETE SIX- AND TWELVE-MONTH INSPECTIONS OF MOTOR GENERATOR

NAME ____________________________________ SCORE ______________

Regular inspections can uncover potential problem areas. Once a problem is noted, a technician can use a service manual to solve the problem or a technician can notify a service contractor.

Complete the inspection as outlined below. Initial and turn in to the instructor.

(CAUTION: Make sure that machine is degenergized before completing inspection routine.)

Part I — Six-month inspection

	YES	NO
A. Commutators		
1. Discolored	_____	_____
2. Uneven	_____	_____
3. Signs of arcing	_____	_____
4. Dirty slots	_____	_____
B. Brushes		
1. Space between brush and commutator	_____	_____
(NOTE: Replace brush when one-half of it is worn away.)		
2. Loose brush rigging	_____	_____
3. Improper setting	_____	_____
4. Loose bolts	_____	_____
5. Loose spring fingers	_____	_____
C. Cooling air passages and openings — Dusty or dirty	_____	_____
(NOTE: Blow out dust and dirt, but do not use high-pressure air on insulation.)		

ASSIGNMENT SHEET #2

		YES	NO
D.	Insulation — Poor condition or dirty	____	____
	(NOTE: Pick up all dust from insulation with vacuum cleaner.)		
E.	Drain — Poor condition or dirty	____	____
	(NOTE: Wash out and renew oil in bearings housing.)		
F.	Open ball and roller bearings — Insufficient grease	____	____
G.	Shaft or rotor end — End play	____	____
H.	Unit bolts		
	1. Loose end bell bolts	____	____
	2. Loose foot bolts	____	____
	3. Loose setscrews	____	____
	4. Loose guard bolts	____	____
I.	Covers and guards — Missing or loose	____	____
J.	Electrical supply and controls		
	1. Circuit breaker inoperable	____	____
	2. Loose connections	____	____
	3. Discoloration	____	____
	4. Improper fuse size	____	____
	5. Loose fuse clips	____	____
	6. Discolored fuse clips	____	____
K.	Motor starting contactor		
	1. Dirty or dusty	____	____
	2. Loose screws	____	____
	3. Pitted contacts	____	____

ASSIGNMENT SHEET #2

	YES	NO
4. Armature and contact bar binding	_____	_____
5. Improper sizing of overload heater units	_____	_____
L. Painting — Repainting needed	_____	_____
M. Safety guards — Additional guards needed	_____	_____

N. Air gap between rotor and stator laminations

1. Record air gap at top of rotor (DC end) ____________
2. Record air gap at top of rotor (AC end) ____________
3. Record air gap at bottom of rotor (DC end) ____________
4. Record air gap at bottom of rotor (AC end) ____________
5. Record air gap at near side of rotor (DC end) ____________
6. Record air gap at near side of rotor (AC end) ____________
7. Record air gap at back side of rotor (DC end) ____________
8. Record air gap at back side of rotor (AC end) ____________

O. Clearance between unit shaft and journal boxes of sleeve bearing units

1. Record clearance (DC end) ____________
2. Record clearance (AC end) ____________

P. Connections between commutator segments and armature coils

(NOTE: Turn unit slowly and examine carefully.)

1. Record number of good connections ____________
2. Record number of connections needing attention ____________

Q. Speed of unit

1. Record nameplate identification number ____________
2. Record nameplate rpm ____________

ASSIGNMENT SHEET #2

3. Record tachometer rpm ______________

R. Armature banding — Record condition ______________

(NOTE: Turn unit slowly to inspect banding around the armature.)

PART II — Twelve-month inspection

Repeat six-month inspection. Check the following additional items while the unit is operating.

		YES	NO
A.	Worn gears	_____	_____
B.	Worn couplings	_____	_____
C.	Noisy motor	_____	_____
D.	Vibrations	_____	_____
E.	Record speed (rpm)	______________	
F.	Record time needed to reach normal speed (rpm)	______________	
G.	Record running amperage	______________	
H.	Record nameplate amperage	______________	

(NOTE: Show your work to the instructor for evaluation and comments.)

MOTOR GENERATORS
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1 — Evaluated to the satisfaction of the instructor

Assignment Sheet #2 — Evaluated to the satisfaction of the instructor

MOTOR GENERATORS
UNIT I

JOB SHEET #1 — SUPERVISE THE REPAIR OF AN UNEVEN COMMUTATOR

(NOTE: It is necessary to seek the services of a machinist to repair an uneven commutator. It is recommended that the electrical technician remain with the machinist during repair process.)

I. Equipment and materials

A. Armature from an electric drill

(NOTE: Because motor generator armatures are expensive parts, you will be using an inexpensive armature from an electric drill.)

B. Crocus cloth (fine 00 grade)

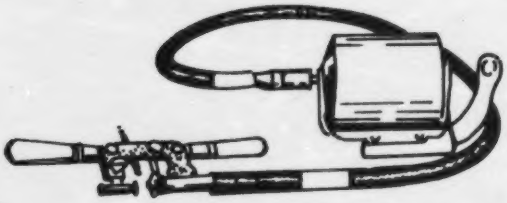
C. Screwdriver set

D. Combination wrench set

E. Hammer

F. Mica undercutting tool (Figure 4)

FIGURE 4

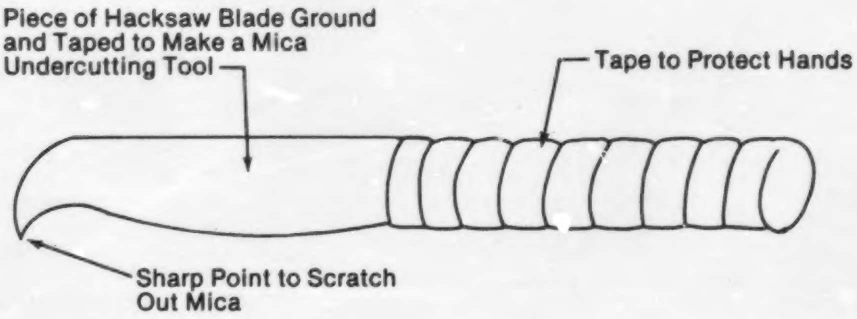


Suspension-Type Flexible-Shaft Undercutter

(NOTE: An old hacksaw blade can be made into an undercutter. See Figure 5.)

JOB SHEET #1

FIGURE 5


Piece of Hacksaw Blade Ground and Taped to Make a Mica Undercutting Tool
Tape to Protect Hands
Sharp Point to Scratch Out Mica

II. Procedure

A. Disassemble drill motor; handle armature very carefully

B. Take commutator to machine shop for repair

1. Advise machinist to make finish cut very lightly and to slow traverse feed of cutting tool; observe to see that finish cut is completed properly

2. Advise machinist to undercut mica between commutator segments; observe to see that mica is undercut properly

   (NOTE: Remind machinist to use discretion when undercutting. A slotted commutator rotating at high speeds may collect bits of copper, carbon dust, and dirt in the slots, causing shorting between commutator segments.)

3. Remind machinist to use appropriate speed for sanding with crocus cloth; observe to see that commutator is sanded properly

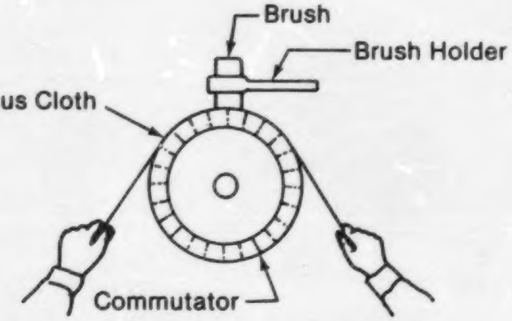
   (CAUTION: Make sure that machinist avoids use of emery cloth on commutator or brushes.)

C. Reassemble drill motor

JOB SHEET #1

D. Install new motor brushes in brush holders and seat properly using crocus cloth (Figure 6)

FIGURE 6



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E. Properly lubricate motor

(NOTE: Show work to instructor for evaluation and comments.)

F. Hook up and operate drill motor when given approval

G. Clean work area; clean and put away equipment and materials

MOTOR GENERATORS
UNIT I

TEST

NAME ______________________________ SCORE ______________

1. Match terms associated with motor generators to their correct definitions. Write the correct numbers in the blanks.

_____a. Data and instructions furnished by manufacturer with each piece of equipment; best source of information about a piece of equipment

_____b. Graphite or carbon blocks that ride on surface of commutator to pick up energy generated by generator

_____c. Rotating part of a generator or motor

_____d. Abrasive stone used to dress or refinish commutator surface

_____e. Stationary part of a generator or motor

_____f. Process of cutting mica insulation to a depth of approximately 1/16 inch below face of commutator segments

_____g. Stationary coils fastened to stator

_____h. Insulated mechanical holder and supports for graphite or carbon brushes

_____i. Insulation between each commutator segment and those adjacent to it

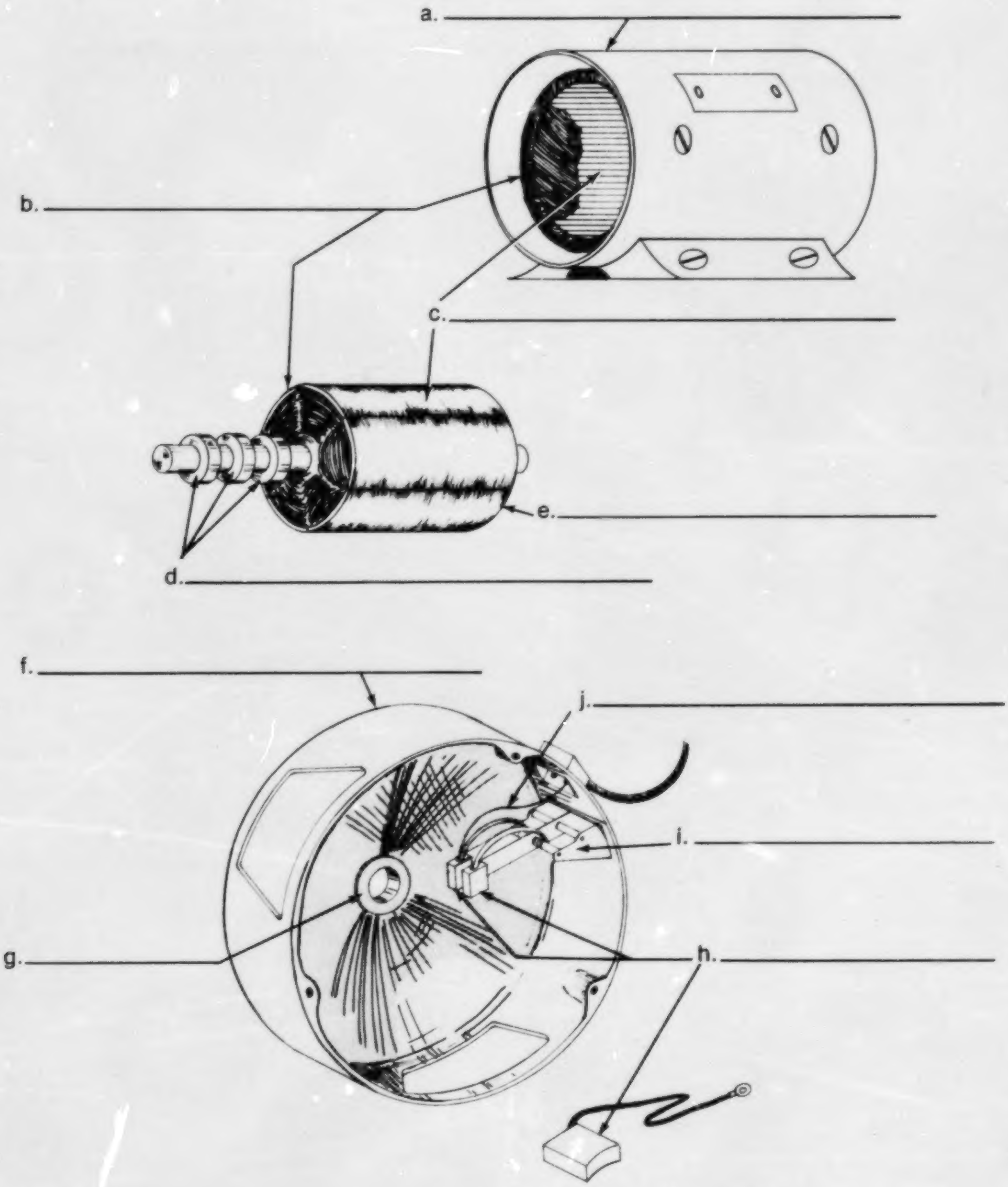
_____j. Copper bar segments on which brushes ride

_____k. Ring located around generator or motor shaft in sleeve bearing housing; used to pick up oil from lower pool of oil and carry it to top of shaft and bearing

1. Instruction book or leaflet
2. Commutator
3. Brushes
4. Brush holder or brush rigging
5. Mica
6. Mica undercutting
7. Handstone
8. Oil ring
9. Armature
10. Field coils
11. Stator

TEST

2. Label the principal parts of the motor generator illustrated below.


a.
b.
c.
d.
e.
f.
j.
i.
g.
h.

TEST

3. Name uses of motor generators.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

4. Name functions of motor generators.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

5. Select from the following list guidelines for lubricating bearings properly. Write an "X" in the blank before each correct answer.

_____a. Check motor shaft for adequate length and diameter

_____b. Use SAE 10W-40 or equivalent lubricant in motor generator bearings

_____c. Check for free movement of shaft and adequate end play

_____d. Place lubricant on commutator with fingers, leaving a fine film of oil

_____e. Provide enough lubricant in bearings to cover start-up

_____f. Cover unused portion of lubricant to protect from dirt, dust, and other contaminants

_____g. Use lubricant specified by manufacturer if possible

6. Select from the following list guidelines for proper care of commutators. Write an "X" in the blank before each correct answer.

_____a. Lubricate heavily with petroleum jelly

_____b. Keep commutator smooth and round

_____c. Apply a coat of insulating paint

TEST

______d. Keep all oil off commutator

______e. Dry insulation thoroughly

______f. Make periodic inspections to detect discoloration or any other defects

______g. Allow oil to penetrate mica insulation between segments

7. List checks to make when inspecting brush assembly.

    a. ______________________________

        1) ______________________________

        2) ______________________________

        3) ______________________________

        4) ______________________________

    b. ______________________________

    c. ______________________________

    d. ______________________________

8. Arrange in order the procedures for cleaning insulation. Write a "1" before the first step, a "2" before the second step, and so on.

______a. Apply coat of insulating paint if indicated

______b. Clean with a vacuum cleaner

______c. Test insulation with megohmmeter

______d. Dry insulation thoroughly before testing or returning to service

______e. Clean air circulation passages

______f. Clean greasy surfaces with approved petroleum solvents

(NOTE: Test questions 9-11 list the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Complete weekly inspection of motor generator.

10. Complete six- and twelve-month inspections of motor generator.

11. Demonstrate the ability to supervise the repair of an uneven commutator.

MOTOR GENERATORS
UNIT I

ANSWERS TO TEST

1.

a.	1	d.	7	g.	10	j.	2
b.	3	e.	11	h.	4	k.	8
c.	9	f.	6	i.	5		

2. a. Stator
   b. Insulated windings
   c. Poles
   d. Slip rings
   e. Rotor
   f. End bell
   g. Bearings
   h. Brushes
   i. Brush rigging
   j. Pigtail shunt

3. a. Electronic equipment
   b. Computer rooms
   c. Radio rooms
   d. Isolation of power from electrical system

4. a. Stabilizing power
   b. Isolating equipment from electrical system
   c. Removing harmonic disturbances
   d. Removing transient voltage spikes
   e. Providing brownout protection

5. c, e, f, g

6. b, d, f

7. a. Brushes
      1) Move freely in holder
      2) Not worn

ANSWERS TO TEST

    3) Do not chatter
    4) Have proper setting
  b. Brush faces have no embedded copper chips
  c. Pigtail shunts are properly attached to brushes and holders
  d. Spring has proper tension

8. a. 3
   b. 1
   c. 6
   d. 4
   e. 5
   f. 2

9. Evaluated to the satisfaction of the instructor

10. Evaluated to the satisfaction of the instructor

11. Performance skills evaluated to the satisfaction of the instructor